GENETIC VARIABILITY ANALYSIS IN OKRA USING MORPHOLOGICAL MARKER

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CERTIFICATE

This is to certify that the thesis entitled **"Genetic Variability Analysis in Okra Using Morphological Marker"** submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Horticulture**, embodies the result of a piece of *bona fide* research work carried out by **Shyam Chandra Halder**, Registration No. **06-02033** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

Date: June, 2013
Dhaka, Bangladesh

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DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted during the period from April to September 2011 at the Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur. Thirty three okra lines and BARI Dherosh 1 were used as check. The single factor experiment was laid out in a Randomized Complete Block Design with three replications. It was revealed that the maximum number of fruit (40.33) was found in AE 050, whereas minimum (21.00) in AE 013 and the highest yield (23.85 t/ha) was in AE 018, whereas lowest (9.32 t/ha) in AE 003. For all traits, phenotypic variance was higher than the genotypic variance with high heritability and high genetic advance in percentage of mean. Data revealed that significant positive association for yield ha^{-1} of okra lines with number of internodes/plant (0.390), plant height (0.655), individual fruit weight (0.629), length of fruit (0.369), diameter of fruit (0.389), number of fruits/plant (0.824) and yield/plant (0.824), while the significant negative association for yield ha^{-1} (-0.319) and non significant negative association with number of branches/plant (-0.007). Path analysis revealed that all the parameters showed positive direct effect except days to 1^{st} flowering and number of branches/plant on yield ha^{-1}. For cluster analysis, four clusters were formed, whereas Cluster II had the highest intra-cluster distance (0.4809) and the highest inter-cluster distance (13.288) was between cluster I and III. On the basis of performance study, considering all the parameters AE 018, AE 050 and AE 212 were selected superior in higher yield and tolerant to YVMV infestation.

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CHAPTER I

INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) is a popular vegetable belongs to the family Malvaceae and is an annual vegetable crop grown in tropical and sub-tropical parts of the world (Tahkur and Arora, 1986). It is well distributed throughout the Indian sub-continent and East Asia (Rashid, 1990). Okra is specially valued for its tender and delicious edible pods which are rich sources of vitamins and minerals. Tender green pods of okra contains approximately 86.1% water, 2.2% protein, 0.2% fat, 9.7% carbohydrate, 1.0% fibre and 0.8% ash (Purseglove, 1987). The pods have some medicinal value with mucilaginous preparation which may used as plasma replacement or blood volume expander (Savello *et al.*, 1980). In Bangladesh the total production of okra is about 42,000 thousand tons which was produced from 10,122 hectare of land in the year 2009 with average yield about 5.15 t/ha which is very low (BBS, 2010) compared to that of other developed countries where the yield is as high as 7.0-12.0 t/ha (Yamaguchi, 1998).

In Bangladesh, vegetable production is not uniform round the year and it is plenty in winter but less in quantity in the summer season. Around 30% of total vegetables are produced during *kharif* season and around 70% in the *rabi* season (Anon., 1993). Therefore, okra can get an importance in *kharif* season as well as summer season in our country context. There are variations of the per capita consumption of vegetables in SAARC countries, where it was in Pakistan (69 g), Srilanka (120 g), and India (135 g) and all are higher than that of Bangladesh (35 g). Although, many dietitians prescribed that the daily requirements of vegetables for an adult person is approximately 285 g (Rampal and Gill, 1990). As a result, malnutrition is very much evident in our country. Successful okra production may contribute partially in solving vegetable scarcity of summer season for the Bangladeshi people.

The low yield of okra in Bangladesh however, is not an indication of low yielding potentiality of this crop, but may be attributed to a number of reasons, viz. unavailability of quality seeds of high yielding varieties in appropriate time, fertilizer management, disease and insect infestation, improper or limited irrigation facilities and other appropriate agronomic practices. Among the factors genotypes/cultivars with high yield potentiality is important one. There are many genotype(s)/cultivars of okra having diverse characters in different parts of the country. Those genotypes are available in the market without any uniformity and standard nomenclature. Genetic diversity can be expressed as the extent to which heritable material differ within a group of plants (van Hintum, 1995). The diversity of a crop in a plant population is the result of evolution. Alternatively, it is the result of natural selection, spontaneous mutation, dispersion and selection by human beings consciously or subconsciously.

The variability among different genotypes of a species is known as genetic diversity. It arises either due to geographical separation or due to genetic barriers to crossability. Genetic diversity plays an important role in plant breeding because hybrids between lines of diverse origin generally display a great heterosis than those between closely related strains (Singh, 1983) which permits to select the genetically divergent parents to obtain the desirable recombination of the segregating generations. The choice of the most suitable breeding method for the rational improvement of yield and its components in any crop largely depends upon the genetic variability, correlations and association between qualitative and quantitative characters, heritability estimates, and adaptability parameters in different environments. Hence, to formulate a successful breeding program for yield, studies on the association of yield components are very important. The variability available in a population could be partitioned into heritable and non-heritable components with aid of genetic parameters, such as, genotypic coefficient of variation, heritability and genetic advance, which also serve as a basis for selection. Improvement in yield and quality of any crop is achieved by selecting genotypes with desirable character combinations that are generally present in the nature or genetic manipulation of diverse parents through hybridization program (Golakia and Maken, 1992).

Multivariate analysis with D^2 technique measures the amount genetic diversity in a given population in respect of several characters. It is one of the potent techniques for measuring the genetic divergence both in intra and inter cluster level. If a plant breeding program is to be advanced more rapidly and efficiently, knowledge of inter-relationships between yield contributing characters is necessary. Thus, determination of correlation between characters has a considerable importance in selection practices, since it helps in the construction of selection indices and also permits for the prediction of correlated response. The development of an intensive breeding and improvement program needs detailed biological information and an understanding of genetic variation for yield and its components. There must be a thorough knowledge of the existence of genetic variability, correlations between yield and its components and divergence of the genotypes.

Considering the above mentioned facts this research work was under taken with the following objectives:

1. To evaluate the performance of okra genotypes for yield and yield contributing characters;
2. To asses the relationship between yield and different yield contributing characters;
3. To study genetic diversity and selection of parents for hybrid development.
4. To find out the best genotype aiming to release as variety.

CHAPTER II

REVIEW OF LITERATURE

Very few research reports are available on the improvement of this crop have been done in Bangladesh. Research effort on variability, correlation between different characters, heterosis and combining ability in okra seems to be also meager. However, some of the important and informative works conducted at home and abroad in this aspect reviewed under the following headings:

2.1 Variability

Perdosa *et al*. (1983) observed wide variation among 100 okra introductions at the University of Viscosa, Brasileia. They observed days from sowing to the end of the juvenile period varied from 43 to 63 days, first anthesis from 52 to 85 days and for the cultural cycle from 131 to 227 days. Plant height at the end of the cultural cycle varied from 73 to 240 cm. Percentage of fruit set varied from 57.4 to 92.9%. Fruit length varied from 12 to 28 cm, fruit diameter from 1.9 to 2.6 cm and mean number of seeds per fruit from 54 to 130. The weight of 100 seeds varied from 5.53 to 7.43.

Martin and Rhodes (1983) studied variability of 95 accessions of *A. esculentus* and *A. tetraphylous*. They found significant differences among the accessions for all the characters studied, viz. plant height, plant spread, number of primary branches per plant, days to flowering, nodes where the first flower appear, number of leaf per plant, leaf length, leaf breadth, petiole length, number of pod per plant, pod weight and total yield.

Geneif (1984) evaluated okra lines under irrigation for yield, quality, disease resistance and general adaptation and found wide variation. Some of the lines showed high yielding capacity and superior attributes especially pod colour, surface and cooking qualities. Two lines namely ‘OL-6’ and ‘OL-8’ were tested over three seasons. The dark green colour and smooth surface of their pods had advantage in export markets. Other lines showed average performance but good cooking qualities.

Rath *et al*. (1991) reported that the improvement of okra through phenotypic selection would be effective for characters like plant height, number of branches per plant, number of nodes per main stem, fruit length, yield per plant and seeds per fruit. On the other hand Ajmal *et al*. (1979) and Arumuga *et al*. (1981) reported that increased fruit yield in okra was obtained due to days to flowering first fruiting node, total fruiting node and number of fruits per plant.

A survey on okra (*A. esculentus* L.) in India was undertaken by National Bureaus for Plant Genetic Resource (NBPGR) under the International Board for plant Genetic Resources (IBPGR) supported project by Verma (1993). He showed that okra accessions had variability for morphology, viz. plant height (60-250 cm) and fruit length (5-25 cm).

Hussein *et al.* (1994) evaluated six local ecotypes and six exotic cultivars of okra for yield and yield components. Significant difference was observed among the accessions for the studied traits. The highest yielding genotype was 'Balady'. Green and the highest yielding cultivar was 'Clemon Spineless'.

Dash and Mishra (1995) worked on variation and character association of fruit yield and its component characters in 27 okra genotypes. They reported that all genotypes differed significantly for fruit yield per plant, fruit length, fruit girth fruit weight, number of seeds per fruit and seed weight per fruit.

Genotypic and phenotypic variances, genotypic and phenotypic coefficient of variation and heritability were estimated for 11 characters in okra for two seasons using 171 okra lines of diverse origin by Patil *et al.* (1996). Considerable variations were observed for number of pods per plant, weight of green pod per plant, number of borer infested pods and weight of borer infested pods per plant. The estimates of PCV and GCV ranged from 14.7% for days to flowering to 71.6% for weight of borer-infested pod. The relatively high genetic advance was observed for the characters like plant height, number of good pods per plant and weight of good pods per plant, indicative of likely effectiveness of selection for such characters.

Gill *et al.* (1997) noticed considerable variation from an experiment conducted with ten varieties of okra, which were subjected to morphological characterization. Among various morphological characters, they studied a few distinguishing characters identified. Considerable genetic variation among okra cultivars for fruit yield and its components has also been reported by several authors such as Rao (1972), Singh *et al.* (1974), Kaul and Peter (1978), Mishra and Chhonkar (1979).

Sannigrani and Chaudhury (1998) conducted an experiment at Tezpur, Assam, India during the Kharif seasion of 1991 and 1992 to evaluate the performance of 7 okra cultivars (Arka Abhay, Arka Anamika, BD-1, BD-2, Prabhani Kranti, Punjab 7 and Pusa Swani). The cultivars differed significantly for growth and yield contributing characters. Arka Anamika and Arka Abhay were found to be the most suitable okra cultivars for commercial cultivation in Assam, compared to Pusa Sawani.

Sonia (1999) investigated the genetic variability of 48 okra genotypes in the mid hills, Himachal Prasesh, India during the Kharif season. Marketable fruit yield per plant varied from 154-467 g and yield was higher in genotypes ‘IC-39135’, ‘IC-9856’ and ‘Punjab Padmini’. The genotype ‘IC-39135’ had the highest number of nodes per plant. The genotype ‘LC-12’ had the highest fruit weight followed by Perfect ‘Long Green’, ‘LG-26’, ‘LG-11’ and ‘LG-16’. Days to 50% flowering varied from 44.33 to 71.00 and ‘IC-45791’ was the earliest to flowering among the genotypes. The genotypes ‘IC-14026’ and ‘IC-45796’ had the highest duration of availability of edible pods.

Hazra and Basu (2000) studied the genetic variability of 22 okra cultivars from West Bengal, India during the summer. They reported wide range of variations for plant height, leaves per plant, nodes per plant, days to first flowering, fruit weight, fruits per plant, seeds per fruit, yield plant; moderate variations for primary branches per plant and fruit length, and lesser variations for node to first flowering, ridges per fruit and dry weight of fruit among the 22 cultivars of okra.

Upon examining 30 okra genotypes by Bendale *et al*. (2003) and observed a wide range of genetic variability for yield and yield-contributing characters (first flowering node, days to first harvest, pod length, pod weight, plant height, nodes per plant, internode length, number of branches per plant, moisture content in pod, fruiting period, seeds per pod, 100-seed weight, number of pods per plant and yield per plant). The phenotypic variance (PCV) for all the 15 characters was higher than the genotypic variance (GCV). The number of branches per plant, yield per plant and number of pods per plant showed high GCV and PCV estimates.

Subrata *et al*. (2004) conducted and experiment with twenty-five genotypes of okra were grown in Nadia, West Bengal, India, during kharif 2001 to study the genetic variability of important growth and fruit characters and their relationships. All the 12 characters (days to first flower, days to 50% flowering, plant height at first flower, number of leaves at first flower, node at first flower, number of ridges per fruit, fruit length, fruit width, fruit weight, fruit dry weight, number of fruits per plant and fruit yield per plant) varied significantly among the genotypes. Fruit yield per plant, number of fruits per plant, fruit weight, fruit dry weight and number of leaves per plant at first flower showed high value of genetic coefficient of variation and phenotypic coefficient of variation. High heritability coupled with high genetic advance was recorded for number of fruits per plant, fruit weight and dry weight as well as fruit yield per plant, indicating that these characters are controlled by additive action of polygenes.

Shekhavat *et al*. (2005) carried out an experiment with okra cultivars ‘Azad Ganga’, ‘KS-313’, ‘KS-375’, ‘KS-405’, ‘KS-410’, ‘KS-412’, ‘P-7’, ‘BO-2’, ‘Prabhani Kranti’ and ‘Pusa Sawani’, were crossed in a diallel fashion excluding reciprocals during kharif 2000 at Kanpur, Uttar Pradesh, India. Correlation studies were performed using 100 genotypes, i.e. 45 F_1, 45 F_2 and 10 parents. Data were recorded for days to flowering, plant height, number of branches per plant, length of first fruiting node, length and width of fruits, number of fruits per plant and weight of fruits per plant (yield per plant). The genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients, indicating an inherent association among characters. Similarly, the genotypic correlation coefficients were higher in the F_1 generation than in the parental or F_2 generation.

The present investigation was conducted by Akotkar *et al*. (2010) to evaluate the genetic variability of some yield contributing characters, and the genetic diversity in fifty genotypes of okra collected from the NBPGR New Delhi, India. Analysis of variance indicated significant difference among the genotypes for different morphological characters. High values of GCV, PCV, heritability and genetic advance (% of mean) observed for number of fruiting nodes, number of ridges per fruit, plant height and number of fruiting nodes indicated these characters might be controlled by additive genes.

The study was carried out by Saifullah and Rabbani (2010) at the Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Jamalpur, Bangladesh. The materials of the study were consisted 121 okra genotypes collected from different parts of Bangladesh. Genotypic and phenotypic coefficient of correlation revealed that fruit yield per plant had positive significant correlations with internodes per plant, length and diameter of fruit, fruits per plant, average weight of fruit and seeds per fruit but fruit yield had significant negative correlation with days to first flowering.

2.2 Correlation and Path analysis

The interdependency of various morphological characters (viz., plant height, internodal length and height at fruit set, fruit length and girth, 100-seed weight and number of days to 50% flowering and maturity) and dry fruit yield of 44 okra cultivars was evaluated by Gandhi *et al*. (2002). Variation was observed in all 44 cultivars for all characters studied. Association analysis showed that dry fruit yield was highly and significantly dependent on the number of nodes per plant, internodal length, number of fruits per plant and seed yield per plant. The interdependency of other characters on each other was also recorded. Correlation coefficients between characters were significantly negative, indicating that an increase in one variable reduces the other variable.

Path coefficient analysis showed that internodal length had the highest positive direct effect, whereas plant height had the highest negative direct effect on dry fruit yield.

The correlation between the yield and yield attributes of 15 advance lines of okra were determined by Dhankhar and Dhankhar (2002) in a field experiment conducted in Hisar, Haryana, India during the spring and summer seasons of 1998-99. Crop yield showed strong positive association with number of fruits and branches per plant. First fruit node on the stem and number of days to 50% flowering had positive association with yield. Plant height and number of days to 50% flowering had negative association with yield. The number of fruits per plant had positive relationship with number of days to 50% flowering, first fruiting node on the stem and number of branches per plant. The number of fruits per plant and days to 50% flowering had the highest direct effects on fruit yield during the spring and summer of 1998-99.

Thirty divergent genotypes of okra (*A. esculentus*) were studied by Kamal *et al.* (2003) for correlation and path analysis during the kharif season of 2001 in Kanpur, Uttar Pradesh, India. The genotypic and phenotypic correlation coefficients were determined to measure the association among nine quantitative characters. The calculated values of genotypic correlation coefficients were higher than phenotypic correlation coefficients for most of the characters. Yield per plant was positive and highly significantly correlated with number of nodes per plant, width of fruit and number of fruits per plant. Path coefficient analysis revealed that number of fruits per plant and width of fruit had high positive direct effect on yield per plant indicating that these characters may be given due weightage while making selection for crop yield improvement.

Correlation and path coefficient analyses conducted on 27 okra genotypes by Niranjan and Mishra (2003) and data were recorded for fruit yield per plant, flowering initiation, edibility period of fruits, number of fruits per plant, fruit length, number of seeds per fruit, fruit weight, plant height and number of branches per plant. In general, the genotypic correlations were higher than the corresponding phenotypic correlations for all the character combinations. Fruit yield was positively and significantly correlated with edibility period of fruits, number of fruits per plant, fruit length, number of seeds per fruit, fruit weight, plant height and number of branches per plant at both genotypic and phenotypic levels. Associations were significant at the genotypic level only between edibility period of fruits and number of branches per plant. All characters had positive and significant association among each other at both levels. Fruit weight, number of seeds per fruit, fruit length, number of fruits per plant and number of branches per plant had high direct contribution towards yield. Fruit weight exerted the highest positive direct effect (0.507) and the highest genotypic correlation value (0.975) on fruit yield per plant.

Subrata *et al.* (2004) conducted and experiment with twenty-five genotypes of okra were grown in Nadia, West Bengal, India, during kharif 2001 to study the genetic variability of important growth and fruit characters and their relationships. All the 12 characters (days to first flower, days to 50% flowering, plant height at first flower, number of leaves at first flower, node at first flower, number of ridges per fruit, fruit length, fruit width, fruit weight, fruit dry weight, number of fruits per plant and fruit yield per plant) varied significantly among the genotypes. Path coefficient analysis with partitioning of phenotypic correlation revealed that number of fruits per plant and fruit weight had positive and high direct effect on fruit yield, indicating their importance as reliable selection criteria for improvement of yield in okra.

Correlation and path analysis were studied by Jaiprakashnarayan and Ravindra (2004) with 69 okra genotypes for growth, earliness and yield traits in an experiment conducted in Karnataka, India. The results indicated the inverse relationship between growth and earliness characters, but strong association between growth and yield characters. Total yield per plant was positively and significantly correlated with number of fruits per plant, average fruit weight, number of nodes on main stem, fruit length, plant height at 60 and 100 days after sowing (DAS) and number of leaves at 45 and 100 DAS, but negatively and significantly correlated with number of locules per fruit, number of nodes at first flowering and first fruiting. Path analysis revealed that average fruit weight, number of nodes on main stem and number of fruits per plant had high direct effect on total yield per plant. Hence, direct selection for average fruit weight and number of fruits per plant is suggested to improve yield.

Correlation and path analysis studies were studied by Bhalekar *et al*. (2005) out in Pune, Maharashtra, India, during kharif 1999 and 2000 in okra, comprising 7 parents and their 21 crosses, for 14 characters, i.e. plant height, number of branches per plant, number of nodes per plant, internodal length, days to 50% flowering, first fruiting node, number of fruits per plant, fruit diameter, number of locules per fruit, fruit length, tip length of fruit, fruit weight, percentage incidence of yellow vein mosaic virus (YVMV) and fruit yield. It is suggested that the suitable genotype of okra for getting higher fruit yield should be YVMV disease-free, early, long-fruited, tall with maximum internodal length and higher number of fruits, branches and nodes per plant.

Correlation, stepwise multiple regression and path coefficient analysis were used by Adeniji and Aremu (2007) to determine the relationships, direct and indirect effects of agronomic and reproductive characters on pod and seed yield of the West African okra, *Abelmoschus caillei* in Nigeria. Eighteen F_2 generation obtained from hybridization of West African okra were planted for evaluation. Data were collected on agronomic and reproductive characters. Significant differences were observed among the segregating population for pods per branch, seeds per pod, internode distance, seeds per ridge branch length, height at flower bud initiation and height at flowering. A positive correlation was recorded for number of pods per plant and seed weight, height at maturity, ridges per pod and seeds per ridge. The seed weight recorded a positive correlation coefficient with edible pod width, seeds per ridge and pods per plant. The stepwise multiple regression analysis identified two characters (height at maturity and number of pods per plant) to have accounted for 31% of variation observed in seed weight. Mature pod length was responsible for 39% of variability in seed weight. The numbers of ridges per pod and plant height at maturity were responsible for 25% of variation due to regression in pod yield. The path analysis identified plant height at maturity, ridges per pod, pods per plant, mature pod length and seed per ridge as selection indicators for pod and seed yield improvement.

The present investigation was conducted by Sanjay *et al*. (2009) with twenty genotypes viz. ('Pusa Makhmali', 'VRO-6', 'VRO-5', 'Selection-10', 'IIVR-10', 'HRB-10', 'IIVR-11', 'Perkin's Long Green', 'VRO-4', 'HRB-9-2', 'Parbhani Kranti', 'RS-410', 'Punjab-7', 'DOV-91-4', 'D-1-S7-1', 'EMS-S-1', 'Bhindi Vaphy', '315' and 'BO-2') and were sown in randomized block design with 'three replications. The experiment was carried out at Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.). The most important trait, no. of flower/plant was positively and significantly correlated with no. of leaves/plant, diameter of stem and no. of days to flower at genotypic and phenotypic levels. The data also revealed that no. of fruits/branch, no. of fruits/plant and no. of days to flower was positively and significantly correlated at genotypic and phenotypic levels.

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

In a correlation study conducted by Solankey and Singh (2010) with 20 parents (17 lines × 3 testers) and their 51 F_1's, in two different seasons i.e. Kharif and summer, it was revealed that the single fruit weight, number of fruit per plant and number of seeds per fruit were identified as important fruit yield component in Kharif season. However, number of fruits per plant, plant height and stem diameter were most crucial yield component for summer season.

The study was carried out by Saifullah and Rabbani (2010) at the Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Jamalpur, Bangladesh. The materials of the study were consisted 121 okra genotypes collected from different parts of Bangladesh. Path analysis showed that plant height showed medium direct positive effect on fruit yield per plant. This trait had also indirect positive effect with number of fruits per plant and number of seeds per plant. Primary branches per plant had negative direct effect on yield and indirect positive effect with plant height, length of fruit, diameter of fruit, number of fruits per plant, fruit weight, number of seeds per fruit and fruit yield per plant. Number of internodes per plant also showed direct negative effect on fruit yield. The study indicated that number of internodes per plant, length and diameter of fruit, number of fruits per plant, average weight of fruit and seeds per fruit showed significant positive correlation with fruit yield both genotypically and phenotypically. Number of fruits per plant, average weight of fruit, plant height, length of fruit, days to first flowering, number of seeds per fruit and diameter of fruit showed positive direct effect on fruit yield per plant. Emphasis should be given for selection of these characters for improvement of yield in okra.

2.3 Heritability and Combining ability

Partap *et al*. (1980) studied dialed crosses involving seven varieties and 21 F_1 hybrids; both additive and non-additive variances were highly significant for days to 50% flowering, plant height, fruit diameter, fruit length, number of fruits per plant and yield per plant. Estimates of degree of dominance showed partial dominance for days to flowering, plant height and fruit length, complete dominance for fruit diameter and number of fruits per plant and over dominance for yield per plant. High heritability was observed for all the characters except yield per plant, number of fruits per plant and plant height.

Partap and Dhankhar (1980) studied the seven parents diallel analysis of okra to see the combining ability and correlation between parental array means, GCA and SCA effects of crosses. General combining ability variances were higher than that due to specific combining ability for all the characters indicating more importance of additive type gene action. However, significant specific combining ability variances for days to 50% flowering, branches per plant, fruits per branch, seeds per fruit, diameter and length of fruit were also found suggesting the involvement of both additive and non-additive gene actions in their inheritance. High correlation between parental array means and GCA effects were observed. Good general combiners for all the characters were recognized. The crosses showing higher yield per plant involved good general combiners for this character. Three types of epistasis were present for yield. They concluded that for effective selection of superior hybrids, needs for SCA effects estimation was strongly felt in a diallel cross study.

The lack of availability of male sterile lines in okra, or high cost of production by hand emasculation and pollination are the limitations at the moment for breeding hybrid variety of the crop. The additive components of genetic variance played a great role in the inheritance of fruit yield and yield contributing characters and the exploitation for the development of true breeding, better performing homozygous lines is an easy way, and it can be successfully utilized through simple progeny selection. The proportion of additive to non-additive genetic variance increased in F_2 suggesting high proportion due to effect of selfing (Singh, 1983; Singh *et al*., 1985; Singh, 1986; Dhillon, 1992 and Singh, 1993). Therefore, selection is usually started from this generation. The combining ability analysis showed that both additive and non-additive genetic variance are important for all the characters, like yield per plant, number of fruit per plant, fruit weight, fruit length, plant height and number of nodes per plant in okra. The magnitude of non-additive variance was more for yield and fruit weight which suggested the development of F_1 hybrids (Singh, 1986; Dhillon, 1992 and Singh, 1993).

Shukla *et al*. (1989) reported that out of 48 crosses of okra, 20 had positive SCA effects for fruit yield per plant, fruit number, plant height and 24 for length of fruit and fruiting nodes. Negative SCA effects for days to flowering were observed in 25 crosses. Estimates of SCA effects showed that the best cross combinations for different characters were Punjab Padmini × PK, Rashmi × PS, IC-12205 × PK, KS-310 × PS, KS-315 × PS, KS-306 × PK and KS-301 × PS. These crosses also manifested high heterosis for fruit yield over better and standard parent.

Changani and Shukla (1990) studied gene effects using means of six generation viz. P_1, P_2, F_1, F_2, BC_1 and BC_2 in six crosses of okra for nodes on main stem, intermodal length, plant height, branches per plant and pods per plant. Simple additive dominance model could not explain the inheritance of all the characters, which they studied with a few exceptions. The estimates of gene effects showed that both additive (additive and additive × additive) as well as non-additive genetic components (dominance, additive × dominance and dominance × dominance) played an important role for the inheritance of all the characters in majority of the crosses. Selection of desired recombinants and then inter crossing should result in desired genotypes which would be useful for further breeding program. Duplicate as well as complementary types of epistasis were found to be more or less equally important for all the yield and yield contributing characters.

Jawili and Rasco Jr. (1990) reported that GCA mean square were highly significant and greater than SCA mean squares indicating the preponderance of additive gene action for yield and yield contributing characters of okra. Consequently, it was suggested that yield improvement in okra should be achieved through conventional breeding and selection of stable lines rather than utilization of hybrid vigour. Smooth green was the best combiner among the inbreds used, giving the highest GCA estimates in almost all the yield and yield contributing characters measured; Acc. 15, 86-4028, and 86-4029 were, identified as good combiners. Smooth green × 86-4028 had the highest yield of 9.34 t/ha on a plot basis among the hybrids and showed a relative good performance in other horticultural traits.

Veeraragavathatham and Irulappan (1991) carried out a 7×7 full diallel analysis using the parents ‘Punjab Padmini’, ‘AE9744’, ‘AE138’, ‘Pusa Sawani’, ‘AE142’, ‘AE180’ and ‘AE824’. ‘PS11’. The GCA variance was higher than the SCA variance for all examined characters. The reciprocal effect was significant for four traits viz. individual fruit weight, fruit length, fruit girth and plant height at final harvest. The best general combiner for yield per plant was ‘AE974’, with the best specific combination being ‘AE824’, PS11 × AE180.

Chaudhary *et al*. (1991) studied the combining ability of okra using 15 F_1hybrids along with their 8 parents (Pusa Sawani, Selection 6-2, Selection 2, Pusa Makhmali and 67/82/26 as females and P_7, Parbhani Kranti and Punjab Padmini as males). The line Pusa Makhmali and the tester Punjab Padmini proved to be good general combiners for yield and yield components. The most promising F_1 hybrid was Pusa Sawani × P_7, for it had the highest SCA for yield per plant, fruits per plant and days to first picking of fruit.

Poshiya and Vashi (1995) carried out an experiment to study the combining ability over three environments for fruit yield and its eight contributing characters using 9 x 9 parental diallel F_1 progenies in okra. Both GCA and SCA were influenced by environments. It was suggested that to have unbiased estimates of GCA and SCA, the material should be tested over a wide range of environments. Both additive and non-additive variances were important for all the characters studied. However, the variances due to GCA were higher in magnitude than their respective SCA counter parts for all the characters. The performance of the parents may give a good indication of their GCA effects. The additive and non-additive variances may be exploited following intermating among the progenies within and between promising crosses in early segregating generations.

Hoque and Hazarika (1996) evaluated the progenies of diallel crosses of six okra cultivars for 11 quantitative traits. Days to flowering, branches per plant and ridges per fruit were controlled by additive components, while the remaining traits were controlled by non-additive gene action.

Singh *et al*. (1996) reported that in okra GCA and SCA variances were highly significant for all the characters viz. nodes at first flowering, days to first flowering, days to first fruiting, total yield per plant, marketable yield per plant, fruit weight, fruit length, fruits per plant and plant height. They concluded that the predominance of non-additive gene action for all the characters studied including total yield, suggests that non-additive gene action may be exploited by developing F_1 hybrids in okra.

Chandra *et al*. (1997) evaluated the parents F_1, F_2, F_3, BC_1, and BC_2 generations of five crosses of okra for estimation of gene effects for five quantitative characters, namely number of pods per plant, length of pod, girth of pod, number of seeds per pod and pod yield per plant. Additive and dominance effects were important for most of the characters in the majority of the crosses. Additive x additive, additive × dominance and dominance x dominance interactions were also significant in most of the crosses.

Singh and Singh (1997) reported some selection parameters of breeding values for yield and its eight component traits in okra by fractional diallel analysis. High heritability and partial dominance were recorded for fruit thickness, fruit length and first fruiting node. Internodal length showed moderate heritability. Low estimates of heritability and over-dominance were observed for yield and four component traits. The magnitude of heritability increased in the F_2 for all characters except days to flowering.

Chandra *et al*. (1998) carried the generation mean analysis of okra in six generations of five crosses in respect of pod yield and its components. Generation mean analysis showed the importance of both additive as well as dominance gene effects, followed by additive and dominance x dominance gene effects.

Ramesh *et al*. (1998) studied the performance of 18 F_1 okra hybrids derived from the crosses of 6 lines with 3 testers for combining ability. Arka Abhay, Pusa Makhmali, Parbhani Kranti and Punjab Padmini were identified as the most promising parents for improving pod yield per plant. Crosses exhibiting significant positive SCA effects for pod yield per plant were IC-9275 × HB-55, Arka Abhay x Punjab Padmini, Arka Abhay × HB-55, Parbhani Kranti × HB- 55, D-2 × EC-16511, P7 × Punjab Padmini, Pusa Makhmli × Punjab and Pusa Makhmali × EC- 16511. Most of the crosses exhibiting SCA effects had at least one parents with good GCA.

In a diallel cross of ten parameters in okra, Arora (2000) observed that the parents Pusa Sawani, Vaishali, Vadhu and Foam Barelley were good general combiners for most of the characters. The crosses Pusa Sawani x Vaishali Vadhu, Vaishali Vadhu × Faom Barelley and Pusa Sawani × Foam Barelley were considered best on the basis of performance and combining ability value. The result revealed that both additive and non-additive genetic variance were important for all the characters i.e. fruit yield, number of fruits, fruit weight, fruit length, plant height and number of nodes.

The above review of literature indicated the importance of a systematic research of okra like characterization of okra genotypes, genetic diversity with morphological, isozymes, correlation among yield contributing characters, heterosis, combining ability of patents and gene actions of governing characters for improvement of the crop.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out during the period from April to August 2011 at BARI, Joydebpur, Gazipur. The materials and methods that were used for conducting the experiment have been presented in this chapter.

3.1 Experimental site

The experiment was conducted in the Olericulture Division, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh. The location of the experimental site is $23^0 74^/$N latitude and $90^0 35^/$E longitude and at an elevation of 8.2 m from sea level.

3.2 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ 28. It had shallow red brown terrace soil. The selected plot was medium high land and the soil series was Ceata (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, Soil Resources Development Institute (SRDI), Farmgate, Dhaka and details of the recorded soil characteristics were presented in appendix I.

3.3 Climatic condition

The experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Details of the meteorological data during the period of the experiment was collected from the Weather Station, BARI, Joydebpur, Gazipur and presented in appendix II.

3.4 Planting materials

In this experiment 33 okra lines and BARI Dherosh 1 were used as experimental materials. Each of the lines was produced in the 2010-2011 cropping season, and the purity and germination percentage were leveled as 90. The source all of the lines used in this experiment was collected from (Plant Genetic Research Centre (PGRC) and Horticulture Research Centre (HRC) of the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

Table 1. Name of okra lines used in the present study

Sl. #	Okra lines	Sl. #	Okra lines
01	AE 001	18	AE 025
02	AE 003	19	AE 026
03	AE 005	20	AE 027
04	AE 011	21	AE 028
05	AE 012	22	AE 029
06	AE 013	23	AE 030
07	AE 014	24	AE 031
08	AE 015	25	AE 032
09	AE 016	26	AE 050
10	AE 017	27	AE 051
11	AE 018	28	AE 052
12	AE 019	29	AE 053
13	AE 020	30	AE 137
14	AE 021	31	AE 146
15	AE 022	32	AE 147
16	AE 023	33	AE 212
17	AE 024	34	BARI Dherosh 1

3.5 Land preparation

The plot selected for conducting the experiment was opened in the third week of March, 2011 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good tilth. Weeds and stubbles were removed and finally obtained a desirable tilth of soil for sowing okra seeds. All weeds, stubbles and residues were eliminated from the field. Finally, a good tilth was achieved. The soil was treated with insecticides (Cinocarb 3G @ 4 kg/ha) at the time of final land preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

3.6 Design and layout of the experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 669.5 m^2 with length 51.5 m and width 13.0 m. The total area was divided into three equal blocks. Each block was divided into 34 plots where 34 okra lines were allotted at random. There were 102 unit plots altogether in the experiment. The size of the each plot was 3.0 m × 1.0 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively.

3.7 Application of manure and fertilizers

Urea, Triple super phosphate (TSP) and Muriate of Potash (MP) were used as a source of nitrogen, phosphorous, and potassium, respectively. Manures and fertilizers that were applied to the experimental plot presented in table 2. The total amount of cowdung, TSP and MP was applied as basal dose at the time of final land preparation and urea was applied at 15, 30 and 45 days after sowing (DAS).

Table 2. Dose and method of application of fertilizers in okra field

Fertilizers	Dose (ha)	Application (%)			
		Basal	15 DAS	30 DAS	45 DAS
Cowdung	10 tons	100	--	--	--
Urea	150 kg	--	33.33	33.33	33.33
TSP	100 kg	100	--	--	--
MP	150 kg	100	--	--	--

3.8 Seeds sowing

The okra seeds were sown in the main field at 04 April, 2011. Seeds were treated with Bavistin @ 2 ml/L of water before sowing the seeds to control the seed borne diseases. The seeds were sown in solid rows having a depth of 2-3 cm with maintaining distance from 60 cm and 40 cm from row to row and plant to plant, respectively.

3.9 Intercultural operation

3.9.1 Irrigation

Light watering was given by a watering cane at every morning and afternoon and it was continued for a week for rapid and well establishment of the germinated seedlings.

3.9.2 Gap filling

The seedlings in the experimental plot were kept under careful observation. Very few seedlings were damaged after germination and such seedling were replaced by new seedlings. Replacement was done with healthy seedling having a boll of earth which was also planted on the same date by the side of the unit plot. The replacement seedlings were given watering upto 7 days after replacement for their proper establishment.

3.9.3 Weeding

The hand weeding was done 15, 30 and 45 days after sowing to keep the plots free from weeds.

3.9.4 Pest and disease control

Insect infestation was a serious problem during the period of establishment of seeding in the field. In spite of Cirocarb 3G applications during final land preparation few young plants were damaged due to attack of mole cricket and cut worm. Cut worms were controlled both mechanically and spraying Darsban 29 EC @ 3%. Some discolored and yellowish diseased leaves were also collected from the plant and removed from the field.

3.10 Harvesting

Fruits were harvested at 5 days interval based on edible maturity. Harvesting was started from 21 May, 2011 and was continued up to September 2011.

3.11 Data collection

Five plants were randomly selected from the middle rows of each unit plot for avoiding border effect, except yields of plots, which was recorded plot wise. Data were collected in respect of the following parameters to assess plant growth; yield attributes and yields as affected by different treatments of the experiment.

3.11.1 Days to flowering

Difference between the dates of sowing to the date of flowering in a plot was counted as days to flowering. Days to flowering was recorded from 5 plants when plants of a plot were at the flowering stage.

3.11.2 Number of branches/plant

The total number of branches/plant was counted from each selected plant. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot.

3.11.3 Number of internodes/plant

The total number of internodes/plant was counted from each selected plant. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot.

3.11.4 Plant height at last harvest

Plant height at last harvest was measured from sample plants in centimeter from the ground level to the tip of the longest stem of five plants and mean value was calculated.

3.11.5 Individual fruit weight

The weight of individual fruit was measured with a digital weighing machine from 10 selected marketable fruits from each selected plots and there average was taken and expressed in gram.

3.11.6 Length of fruit

The length of fruit was measured with a meter scale from the neck of the fruit to the bottom of 10 selected marketable fruits from each plot and there average was taken and expressed in cm.

3.11.7 Diameter of fruit

Diameter of fruit was measured at the middle portion of 10 selected marketable fruit from each plot with a digital calipers-515 (DC-515) and average was taken and expressed in cm.

3.11.8 Number of fruits/plant

The number of fruits/plant was counted from the sample plants for the whole growing period and the average number of fruits produced/plant was recorded and expressed in fruits/plant.

3.11.9 Yield/plant

Yield of okra/plant was recorded as the whole fruit/plant weighing by a digital machine for the whole growing period and was expressed in gram.

3.11.10 Yield/hectare

Yield/hectare of okra fruits was estimated by converting the weight of plot yield into hectare and was expressed in ton.

3.11.11 YVMV (Yellow vein mosaic virus) infestation

The numbers of YVMV infested plants were identity on per plot basis on the basis of symptom and recorded plot wise and finally converted into percentage.

3.12 Statistical analysis

The data obtained for different characters were statistically analyzed using MSTAT-C software to find out the significance of the difference for different okra lines. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the ‘F’ (variance ratio) test. The significance of the difference among the means of treatment combinations was estimated by

Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

3.13 Estimation of variability

Genotypic and phenotypic coefficient of variation and heritability were estimated by using the following formulae:

3.13.1 Estimation of components of variance from individual environment

Genotypic and phenotypic variances were estimated with the help of the following formula suggested by Johnson *et al*. (1955). The genotypic variance (σ^2_g) was estimated by subtracting error mean square (σ^2_e) from the genotypic mean square and dividing it by the number of replication (r). This is given by the following formula -

$$\text{Genotypic variance } (\sigma^2_g) = \frac{MS_V - MS_E}{r}$$

Where,

MS_V = lines mean square

MS_E = error mean square

r = number of replication

The phenotypic variance (σ^2_p), was derived by adding genotypic variances with the error variance, as given by the following formula –

$$\text{Phenotypic variance } (\sigma^2_{ph}) = \sigma^2_g + \sigma^2_e$$

Where,

σ^2_{ph} = phenotypic variance

σ^2_g = genotypic variance

σ^2_e = error variance

3.13.2 Estimation of genotypic co-efficient of variation (GCV) and phenotypic co-efficient of variation (PCV)

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated following formula as suggested by Burton (1952):

$$\% \text{ Genotypic coefficient of variance } = \frac{\sigma_g}{\overline{x}} \times 100$$

Where,

σ_g = genotypic standard deviation

$\overline{x}$ = population mean

$$\% \text{ Phenotypic coefficient of variance } = \frac{\sigma_{ph}}{\overline{x}} \times 100$$

Where,

σ_{ph} = phenotypic standard deviation

$\overline{x}$ = population mean

3.13.3 Estimation of heritability

Heritability in broad sense was estimated following the formula as suggested by Johnson *et al*. (1955):

$$\text{Heritability } (\%) = \frac{\sigma^2_g}{\sigma^2_{ph}} \times 100$$

Where,

σ^2_g = genotypic variance

σ^2_{ph} = phenotypic variance

3.13.4 Estimation of genetic advance

The following formula was used to estimate the expected genetic advance for different characters under selection as suggested by Allard (1960):

$$GA = \frac{\sigma^2_g}{\sigma^2_p} \times K.\ \sigma_p$$

Where,

GA = Genetic advance

σ^2_g = genotypic variance

σ^2_{ph} = phenotypic variance

σ_{ph} = phenotypic standard deviation

K = Selection differential which is equal to 2.64 at 5% selection intensity

3.13.5 Estimation of genetic advance in percentage of mean

Genetic advance in percentage of mean was calculated by the following formula given by Comstock and Robinson (1952):

$$\text{Genetic Advance in percentage of mean} = \frac{\text{Genetic advance}}{\bar{x}} \times 100$$

3.14 Estimation of correlation

Simple correlation was estimated of the 12 traits with the following formula (Singh and Chaudhary, 1985):

$$r = \frac{\sum xy - \frac{\sum x.\sum y}{N}}{\left[\left\{\sum x^2 - \frac{(\sum x)^2}{N}\right\}\left\{\sum y^2 - \frac{(\sum y)^2}{N}\right\}\right]^{1/2}}$$

Where,

$\sum$ = Summation

x and y are the two variables

N = Number of observations

3.15 Path co-efficient analysis

Path co-efficient analysis was done according to the procedure employed by Dewey and Lu (1959) also quoted in Singh and Chaudhary (1985) using simple correlation values. In path analysis, correlation co-efficient is partitioned into direct and indirect of independent variables on the dependent variable.

In order to estimate direct and indirect effect of the correlated characters, say x_1, x_2, x_3 yield y, a set of simultaneous equations (three equations in this example) is required to be formulated as given below:

$ryx_1 = Pyx_1 + Pyx_2rx_1x_2 + Pyx_3rx_1x_3$

$ryx_2 = Pyx_1rx_1x_2 + Pyx_2 + Pyx_3rx_2x_3$

$ryx_3 = Pyx_1rx_1x_3 + Pyx_2\, rx_2x_3 + Pyx_3$

Where, r's denotes simple correlation co-efficient and P's denote path co-efficient (unknown). P's in the above equations may be conveniently solved by arranging them in matrix form. Total correlation, say between x_1 and y is thus partitioned as follows:

Pyx_1 = The direct effect of x_1 on y

$Pyx_1rx_1x_2$ = The indirect effect of x_1 via x_2 on y

$Pyx_1rx_1x_3$ = The indirect effect of x_1 via x_3 on y

After calculating the direct and indirect effect of the characters, residual effect (R) was calculated by using the formula given below (Singh and Chaudhary, 1985):

$P^2RY = 1 - \sum Piy.riy$

Where,

$P^2RY = (R^2)$; and hence residual effect, $R = (P^2RY)^{1/2}$

Piy = Direct effect of the character on yield

riy = Correlation of the character with yield

3.16 Analysis of heterosis

For estimation of heterosis in each character the mean values of the 15 lines have been compared with better parent (BP) for heterobeltosis.

The significant test for heterosis was done by using standard error of the value of better parent as;

$SE\ (BP) = \sqrt{3/2 \times MSE/r}$ and

3.17 Statistical procedure adopted for combining ability analysis

Combining ability analysis of the traits with significant genotypic differences were done according to the Model 1 (fixed genotypic effects) and Method 2 (half diallel) of Griffing (1956). The fixed genotypic effect model was more appropriate in the present case since the parents selected were self-pollinated lines and the parents and F_1s were the populations considered. This analysis partitioned the variation due to genotypic differences into general combining ability (GCA) and specific combining ability (SCA) effects.

GCA measures the average performance of parent in hybrid combination, whereas SCA refers to those instances in which the performances of a hybrid is relatively better or worse than would be expected on the basis of the average performances of the parents involved. In an experiment, which includes parents as well as hybrids, analyzed by Griffing's techniques, GCA represents additive gene effect (perhaps modified by epitasis) while SCA represents non-additive gene effects.

3.18 Analysis of genetic divergence

Genetic divergences among the okra lines studied were assessed by using Mahalanobis' D^2 statistics and its auxiliary analysis. Both techniques estimate divergences among a set of okra lines on multivariate scale.

Mahalanobis' D^2 statistics

First the variation among the materials were tested by Wilkin's criteria '^'.

$$\text{`}\wedge\text{'} = \frac{|W|}{|S|} = \frac{|\text{Determination of error matrix}|}{|\text{Determination of error + variety matrix}|}$$

Now, $\text{`v'}_{(stat)} = -m \log_{e\wedge} = -\{n-(p+q+1)/2\}\log_{e\wedge}$

Where,

m = n-(p+q+1)/2
p = number of variables or characters
q = number of varieties – 1 (or df for population)
n = df for error + varieties
e = 2.7183

Data were then analysed for D^2 statistics according to Rao (1952). Error variance and covariance matrix obtained from analysis of variance and covariance were inverted by pivotal condensation method. Using the pivotal elements the original means of the characters (X_1, X_2---------X_8) were transformed into a set of uncorrelated variables (Y_1, Y_2---------Y_8).

Now, the genetic divergence between two varieties/lines (suppose Vi and Vj was calculated as –

$$D^2ij = \sum_{k=1}^{8} (Vik - Vjk)^2$$

Where,

D^2ij = Genetic divergence between ‘i’ th and ‘j’ th lines

Vik = Transformed mean of the ‘i’ th lines for ‘k’ th character

Vjk = Transformed mean of the ‘j’ th lines for ‘k’ th character

The D^2 values between all varieties were arranged in order of relative distances from each other and were used for clusters formation, as suggested by Rao, 1952.

$$\text{Average intra-cluster } D^2 = \frac{\sum D^2 i}{n}$$

Where,

$\sum D^2 i$ = Sum of distances between all possible combinations (n) of the lines included in a cluster.

N = All possible combinations.

CHAPTER IV

RESULTS AND DISCUSSION

The results have been discussed and possible interpretations are given under the following headings:

4.1 Mean performance of yield contributing characters and yield

4.1.1 Days to 1st flowering

Statistically significant variation was recorded for different lines on days to 1st flowering of okra (Table 3). The highest days to 1st flowering (51.67) was observed in AE 032, while the lowest days (41.00) was recorded in AE 018, AE 024 and AE 030. Data revealed that the average days to 1st flowering was 46.10 and around 50% lines required more than that average day required for 1st flowering. Different lines take significantly differed days to first flowering. It indicates that the examined lines were morphologically different from each other in flower bearing habit. Subrata *et al*. (2004) reported that days to first flower varied significantly among the genotypes. Sonia (1999) reported days to flowering varied from 44.33 to 71.00 in okra.

4.1.2 Number of branches/plant

Number of branches/plant of okra varied significantly for different lines (Table 3). The maximum number of branches/plant (4.17) was recorded in AE 022, whereas, the minimum number (1.33) was found in AE 052 and AE 016. The average number of branches/plant was 2.57 and less than 50% lines produced more than the average number of branches/plant. In most of the cases the number of branches/plant was shown marketable difference at early stage of development. Subrata *et al*. (2004) reported that number of branches/plant at first flower varied significantly among the genotypes. Martin and Rhodes (1983) found significant differences among the accessions for number of primary branches/plant.

Table 3. Mean performance of 34 okra lines in respect of quantitative characters (cont'd)

Okra lines	Days require to 1st flowering	Number of branches/plant	Number of internodes/plant	Plant height (m) at last harvest	Individual fruit weight (g)
AE 001	47.00	3.77	23.00	1.10	14.37
AE 003	48.33	4.10	21.50	0.90	12.67
AE 005	50.67	2.20	19.37	0.84	14.03
AE 011	43.00	1.77	20.33	1.20	15.33
AE 012	43.00	3.23	21.37	1.25	13.03
AE 013	50.33	2.20	21.50	1.15	14.23
AE 014	50.67	4.10	16.10	1.10	15.40
AE 015	43.67	3.30	16.83	1.23	16.87
AE 016	42.00	1.33	18.00	1.27	15.37
AE 017	48.00	1.55	21.33	1.25	16.50
AE 018	41.00	3.53	27.53	1.53	18.30
AE 019	43.33	2.17	22.87	1.33	16.83
AE 020	46.00	3.23	21.67	0.93	17.13
AE 021	42.33	3.20	26.87	1.23	12.43
AE 022	48.67	4.17	26.00	1.35	13.30
AE 023	48.33	2.33	25.20	1.32	14.73
AE 024	41.00	1.37	27.23	1.13	18.37
AE 025	44.00	3.50	28.03	1.27	19.30
AE 026	48.33	2.70	26.17	1.25	20.53
AE 027	49.67	3.13	21.37	1.17	12.97
AE 028	45.00	1.85	22.93	1.10	15.40
AE 029	41.67	2.70	19.90	1.25	16.40
AE 030	41.00	2.43	30.07	1.37	14.47
AE 031	50.00	1.73	29.87	1.28	13.43
AE 032	51.67	1.53	22.50	1.07	14.40
AE 050	42.00	1.60	34.23	1.75	17.23
AE 051	49.00	3.23	21.20	0.95	11.97
AE 052	47.33	1.33	17.57	0.85	12.17
AE 053	42.33	1.43	23.23	1.18	11.80
AE 137	47.67	2.47	23.87	1.37	15.53
AE 146	49.00	2.43	24.73	1.45	16.37
AE 147	49.00	2.37	24.37	1.38	15.13
AE 212	41.67	2.43	29.87	1.63	16.69
BARI Dherosh 1	50.60	3.02	29.93	1.53	19.11
Mean	46.10	2.57	23.72	1.23	15.35
SE	1.347	0.243	0.939	0.056	0.487
CV(%)	5.06	16.37	6.86	7.88	5.50

Table 3. Mean performance of 34 okra lines in respect of quantitative characters

Okra lines	Length of fruit (cm)	Diameter of fruit (cm)	Number of fruits/ plant	Yield /plant (g)	Yield/ hectare (ton)	YVMV Infestation (%)
AE 001	12.90	1.38	24.00	359.17	11.80	38.67
AE 003	13.90	1.53	21.67	274.17	9.32	45.33
AE 005	14.90	1.44	22.00	309.20	10.51	56.00
AE 011	13.03	1.37	22.33	343.00	11.66	81.00
AE 012	13.10	1.60	30.33	395.40	13.44	21.00
AE 013	14.40	1.47	21.00	298.83	10.16	91.00
AE 014	13.90	1.60	32.67	503.00	17.10	31.00
AE 015	14.13	1.50	31.33	528.53	17.97	15.33
AE 016	14.53	1.35	30.00	460.80	15.66	51.33
AE 017	15.10	1.35	28.33	467.17	15.89	56.33
AE 018	15.37	1.71	38.33	701.67	23.85	2.67
AE 019	13.60	1.39	31.00	522.20	17.75	58.33
AE 020	13.00	1.50	30.33	519.83	17.68	90.00
AE 021	14.37	1.36	30.33	377.00	12.82	45.00
AE 022	12.20	1.63	29.67	394.57	13.42	40.00
AE 023	12.03	1.57	27.67	407.90	13.87	76.67
AE 024	12.87	1.40	21.33	391.60	13.31	81.67
AE 025	16.57	1.37	22.67	437.33	14.87	32.00
AE 026	13.13	1.39	24.33	499.17	16.97	21.67
AE 027	12.17	1.40	23.33	301.67	10.26	23.33
AE 028	14.87	1.65	31.67	487.00	16.56	71.67
AE 029	14.43	1.57	32.00	524.87	17.84	13.33
AE 030	12.87	1.65	31.00	448.47	15.25	52.33
AE 031	13.33	1.61	31.00	416.40	14.16	83.33
AE 032	14.17	1.66	30.67	441.57	15.01	91.00
AE 050	14.67	1.60	40.33	695.07	23.63	3.00
AE 051	12.90	1.52	23.33	278.33	9.47	31.67
AE 052	13.13	1.31	26.67	321.67	10.94	45.00
AE 053	13.77	1.29	30.33	361.63	12.30	56.67
AE 137	14.87	1.55	31.33	486.17	16.53	61.67
AE 146	13.10	1.60	33.00	527.50	17.93	51.00
AE 147	14.13	1.55	31.67	478.67	16.27	42.67
AE 212	15.10	1.60	37.33	623.87	21.21	5.00
BARI Dherosh 1	15.99	1.66	36.70	693.93	18.52	3.70
Mean	13.90	1.50	29.11	449.33	15.12	46.19
SE	0.432	0.047	1.145	20.12	0.652	0.509
CV(%)	5.38	5.78	6.81	7.76	7.47	6.43

4.1.3 Number of internodes/plant

Different lines of okra showed statistically significant variation for number of internodes/plant (Table 3). It was found that the maximum number of internodes/plant (34.23) was attained in AE 050 and the minimum (16.10) in AE 014. The average number of internodes/plant was 23.72 and 50% lines produced more than the average number of internodes/plant. This parameter also significantly differed from accessions to accessions, it express their separate identity. Arumuga *et al*. (1981) and Ajmal *et al*. (1979) reported that increased fruit yield was obtained due to total fruiting internodes.

4.1.4 Plant height

Plant height of okra varied significantly among different lines under the present trial (Table 3). Data revealed that the average plant height was 1.23 m and most of the okra lines produced the tallest plant than the average plant height. The longest plant (1.75 m) was observed in AE 050, while the shortest plant (0.84 m) was recorded in AE 053.The longest plants were shown the higher no. of internodes. The lines were varied in plant height, it also implies that the collected lines were phonotypical dissimilar. Subrata *et al*. (2004) reported that plant height varied significantly among the genotypes. Perdosa *et al*. (1983) reported that plant height at the end of the cultural cycle varied from 73 to 240 cm.

4.1.5 Individual fruit weight

Statistically significant variation was found in terms of individual fruit weight of okra (Table 3). The highest individual fruit weight (20.53 g) was found in AE 026, while the lowest was (11.80 g) recorded in AE 053. The average individual fruit weight was 15.35 g and around 50% lines gave more than that average individual fruit weight. Due to different plant height, length of fruit and other morphological structure of different lines the individual fruit weight of different lines were varied from each other. Mishra *et al*. (1996) and Hazra and Basu (2000) reported that genotypes differed significantly for Individual fruit weight.

4.1.6 Length of fruit

Different lines of okra showed statistically significant differences for on length of fruit (Table 3). It was found that the average length of fruit was 13.90 cm and about fifty percent okra lines produced the longest fruit than that average fruit length. The highest length of fruit (16.57 cm) was recorded in AE 025, while the lowest length of fruit (12.03 cm) was found in AE 023. The fruit length of okra varied from line to line due to variation in days to first flowering as well as number of internodes per plant and other morphological behavior. Verma *et al*. (1993) and Perdosa *et al.*(1983) found that fruit length of okra genotypes varied from 5.00 to 25.00 cm and 12.00 to 28 cm respectively.

4.1.7 Diameter of fruit

Statistically significant variation was recorded among the different lines in terms of diameter of fruit of okra (Table 3). Data revealed that the average diameter of fruit was 1.50 cm and more than 50% okra lines produced the highest diameter of fruit than that average fruit diameter. The highest diameter of fruit (1.71 cm) was observed in AE 018, while the lowest diameter of fruit (1.29 cm) was recorded in AE 053. Different fruit girth was found due to variation in the accessions. Dash and Mishra (1995) reported that genotypes differed significantly for fruit girth.

4.1.8 Number of fruits/plant

Significant variation was observed among different lines in terms of number of fruits/plant of okra (Table 3). Data revealed that the average number of fruits/plant was 29.11 and more than 60% okra lines produced the highest number of fruits than that average number of fruits/plant. The maximum number of fruit (40.33) was found in AE 050, whereas, the minimum (21.00) was observed in AE 013.The variation was observed due to the variation in the number of fruit bearing internodes as well as the plant height among the lines. Subrata *et al*. (2004) reported that number of fruits/plant varied significantly among the genotypes.

4.1.9 Yield/plant

Yield/plant of okra showed statistically significant variation (Table 3). Data revealed that the average yield/plant was 449.33 g and less than 50% okra lines produced yield more than the average yield/plant. The highest yield/plant (701.67 g) was observed in AE 018 and the lowest (274.17 g) was attained in AE 003 lines. It was observed that the difference in yield/plant among the lines was found due to variation in the number of internodes and days to flowering. Dash and Mishra (1995) reported that genotypes differed significantly for fruit yield/plant.

4.1.10 Yield/hectare

Statistically significant variation was recorded in terms of yield/hectare of okra (Table 3). Data revealed that the average yield/hectare was 15.12 ton and around 50% okra lines produced yield more than the average yield/hectare. The highest yield/hectare (23.85 ton) was observed in AE 018, whereas, the lowest (9.32 ton) was recorded in AE 003. The variation was noticed due to variation in the yield contributing characters of the okra lines. Subrata *et al*. (2004) reported that fruit yield/hectare varied significantly among the genotypes.

4.1.11 YVMV (yellow vein mosaic virus) infestation

Different lines of okra varied significantly for YVMV infestation (Table 3). Data revealed that the average YVMV infested plant was 46.19% and less than 50% okra lines were attacked by YVMV infestation more than the average infestation. The highest YVMV infestation (91.00%) was recorded in AE 032, the lowest (2.67%) was found in AE 018 lines. Most of the okra lines were more or less infected by YVMV and wide range of variation was found. Some okra lines were high yielding along with less YVMV infestation. Bhalekar *et al*. (2005) suggested that the suitable genotype of okra for getting higher fruit yield should be YVMV disease-free.

4.2 Variability study for 11 traits of okra

Genotypic and phenotypic variance, heritability, genetic advance and genetic advance in percentage of mean presented in Table 4.

4.2.1 Days to 1st flowering

In terms of days required to flowering, phenotypic variation (16.11) was higher than the genotypic variance (10.66) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (4.01%) and genotypic (3.27%) co-efficient of variation (Table 4). The moderate difference for this parameter was also suggested a considerable influence of environment for the expression of days to 1st flowering. High heritability (66.18%) in days to 1st flowering attached with moderate genetic advance (7.01%) and moderate genetic advance in percentage of mean (15.21). The high heritability along with moderate genetic advance in percentage of mean days to 1st flowering indicated the possible scope for improvement through selection of the character and breeder may expect reasonable benefit in next generation in consideration of this trait. Patil *et al.* (1996) estimates PCV and GCV ranged from 14.7% to 71.6%. Considerable genetic variation among okra cultivars for fruit components has also been reported by several authors such as Singh *et al*. (1974), Kaul and Peter (1978), Mishra and Chhonkar (1979).

4.2.2 Number of branches/plant

Phenotypic variation (0.86) was higher than the genotypic variance (0.69) indicating low environmental influence on this characters which was supported by narrow difference between phenotypic (0.93%) and genotypic (0.83%) co-efficient of variation for number of branches/plant (Table 4). The difference between these parameters was also low suggested a considerable influence of environment on number of branches/plant for its expression. High heritability (79.48%) in number of branches/plant attached with low genetic advance (1.95%) and high genetic advance in percentage of mean (75.77). High estimate of heritability and low genetic advance were registered in number of branches/plant suggested that this character was not predominantly controlled by environment

Table 4. Genetic parameters of yield contributing characters and yield of okra

Characters	Genotypic variance ($\sigma^2 g$)	Phenotypic variance ($\sigma^2 p$)	Genotypic coefficient of variation (%)	Phenotypic coefficient of variation (%)	Heritability (%)	Genetic Advance (GA)	GA in percentage of mean
Days to 1st flowering	10.66	16.11	3.27	4.01	66.18	7.01	15.21
Number of branches/Plant	0.69	0.86	0.83	0.93	79.48	1.95	75.77
Number of internodes/plant	17.21	19.86	4.15	4.46	86.67	10.20	42.98
Plant height at last harvest	0.04	0.05	0.20	0.22	81.76	0.48	38.85
Individual fruit weight	4.79	5.50	2.19	2.35	87.04	5.39	35.12
Length of fruit	1.00	1.56	1.00	1.25	64.17	2.12	15.24
Diameter of fruit	0.01	0.02	0.11	0.14	63.16	0.23	15.28
Number of fruits/plant	24.74	28.67	4.97	5.35	86.29	12.20	41.90
Yield/plant	12840.20	14054.64	113.31	118.55	91.36	285.93	63.64
Yield/hectare	13.16	14.43	3.63	3.80	91.17	9.14	60.49

with complex gene interaction and genetic improvement of this character would therefore be moderately effective. Bendale *et al*. (2003) reported high GCV and PCV estimates for number of branches per plant.

4.2.3 Number of internodes/plant

It was revealed that phenotypic variation (19.86) was higher than the genotypic variance (17.21) for indicating low environmental influence on this characters which was supported by narrow difference between phenotypic (4.46%) and genotypic (4.15%) co-efficient of variation for number of internodes/plant (Table 4). The difference between these parameters was also low suggested a significant influence of environment on number of internodes/plant for its expression. High heritability (86.67%) in number of internodes/plant attached with high genetic advance (10.20%) and high genetic advance in percentage of mean (42.98). High estimate of heritability and low genetic advance were registered in number of internodes/plant suggested that this character was predominantly controlled by environment with complex gene interaction.

4.2.4 Plant height

From the data it was found the plant height in terms of phenotypic variation (0.05) was higher than the genotypic variance (0.04) indicating high environmental influence on this characters which was supported by narrow difference between phenotypic (0.22%) and genotypic (0.20%) co-efficient of variation (Table 4). The difference between phenotypic and genotypic variation then was high indicated great influence of the environment for the expression of this character. Therefore, the breeder must have to simultaneous consideration of genetic work predicted environment for improving the trait. For plant height, high heritability (81.76%) along with low genetic advance (0.48%) was observed and genetic advance was high in percentage of mean (38.85%). As this trait possessed high variation, it was potential for effective selection for further genetic improvement. Akotkar *et al*. (2010) reported that high values of GCV, PCV, heritability and genetic advance (% of mean) observed for plant height indicated these characters might be controlled by additive genes. Patil *et al.* (1996) observed relatively high genetic advance for the characters like plant height indicative of likely effectiveness of selection for such characters.

4.2.5 Individual fruit weight

Individual fruit weight of okra in respect of phenotypic variation (5.50) was higher than the genotypic variance (4.79) indicating high environmental influence on this characters which was supported by narrow difference between phenotypic (2.35%) and genotypic (2.19%) co-efficient of variation (Table 4). The difference between phenotypic and genotypic variance then was low indicated minimum influence of the environment for the expression of this character. High heritability (87.04%) for individual fruit weight attached with moderate genetic advance (5.39%) was recorded. Genetic advance in percentage of mean (35.12) was also high. The high heritability estimate coupled with moderate expected genetic advance for this trait indicated the importance of both additive and non additive genetic effects for the controlling the character. Genetic improvement of this character would therefore be moderately effective.

4.2.6 Length of fruit

It was observed that length of fruit in terms of phenotypic variation (1.56) was higher than the genotypic variance (1.00) indicating the highest environmental influence on this characters which was supported by narrow difference between phenotypic (1.25%) and genotypic (1.00%) co-efficient of variation (Table 4). The difference between phenotypic and genotypic variation then was minimum indicated moderately influence of the environment for the expression of this character. Therefore, the breeder must have to consecutive consideration of genetic work predicted environment for improving the trait. In case of length of fruit high heritability (64.17%) was recorded attached with low genetic advance (2.12%) and moderate genetic advance in percentage of mean (15.24%). As this trait possessed high variation, it was potential for effective selection for further genetic improvement.

4.2.7 Diameter of fruit

Diameter of fruit in respect of phenotypic variation (0.02) was higher than the genotypic variance (0.01) indicating high environmental influence on this characters which was supported by narrow difference between phenotypic (0.14%) and genotypic (0.11%) co-efficient of variation (Table 4). That mean the very close to phenotypic and genotypic variance which indicated that environment had played a little role with little genetic variation among the lines of this trait i.e. environmental influence was minimum. Therefore, diameter of fruit was the inherent potential among the studied okra lines. It was recorded high heritability (63.16%) for diameter of fruit along with lowest genetic advance (0.23%). Genetic advance in percentage of mean was moderate (15.28) for diameter of fruit. The high heritability along with moderate genetic advance in percentage of mean of diameter of fruit indicated the possible scope for improvement through selection of the character and breeder may expect reasonable benefit in next generation in respect of this trait.

4.2.8 Number of fruits/plant

It was revealed that number of fruits/plant in terms of phenotypic variation (28.67) was higher than the genotypic variance (24.74) indicating high environmental influence on this characters which was supported by narrow difference between phenotypic (5.35%) and genotypic (4.97%) co-efficient of variation (Table 4). The difference between phenotypic and genotypic variation then was high indicated great influence of the environment for the expression of this character. Therefore, the breeder must have to simultaneous consideration of genetic work predicted environment for improving the trait. Heritability (86.29%) for number of fruits/plant was high along with moderate genetic advance (12.20%) and high genetic advance in percentage of mean (41.90). As this trait possessed high heritability, it had potential for effective selection for further genetic improvement. Patil *et al.* (1996) observed relatively high genetic advance for the characters like number of good pods per plant indicative of likely effectiveness of selection for such characters. Bendale *et al*. (2003) reported high GCV and PCV estimates for number of pods per plant.

4.2.9 Fruit yield/plant

Phenotypic variation (14054.64) was higher than the genotypic variance (12840.20) in terms of fruit yield/plant indicating minimum environmental influence on this characters which was supported by narrow difference between phenotypic (118.55%) and genotypic (113.31%) co-efficient of variation (Table 4). The difference between phenotypic and genotypic variation then was minimum indicated moderately influence of the environment for the expression of this character. It was recorded high heritability (91.36%) for fruit yield/plant attached with high genetic advance (285.93%) and genetic advance in percentage of mean (63.64) was very high. As this trait possessed high heritability so the emphasis should be given on this parameter during selection for further varietal improvement. Bendale *et al*. (2003) reported high GCV and PCV estimates for yield per plant.

4.2.10 Fruit yield/hectare

It was revealed that fruit yield/hectare in terms of phenotypic variation (14.43) was higher than the genotypic variance (13.16) indicating minimum environmental influence on this characters which was supported by narrow difference between phenotypic (3.80%) and genotypic (3.63%) co-efficient of variation (Table 4). The difference between phenotypic and genotypic variation then was minimum indicated moderately influence of the environment for the expression of this character. Therefore, the breeder must have to consecutive consideration of genetic work predicted environment for improving the trait. High heritability (91.17%) for fruit yield/hectare was recorded with moderate genetic advance (9.14%) . High genetic advance in percentage of mean (60.49) was recorded. The trait possessed high heritability, it had potential for effective selection for further genetic improvement. Considerable genetic variation among okra cultivars for fruit yield has also been reported by several authors such as Rao (1972), Singh *et al*. (1974), Kaul and Peter (1978), Mishra and Chhonkar (1979).

4.3 Correlation Matrix

To measure the mutual relationship among yield and yield contributing characters of okra correlation matrix analysis was done and also to determine the component characters on which selection could be based for improvement in yield of 34 lines of okra (Table 5).

4.3.1 Days to 1st flowering

Significant negative association was recorded for Days to 1st flowering of okra lines with number of internodes/plant (-0.206), plant height (-0.286), number of fruits/plant (-0.251), yield/hectare (-0.258) and yield/plant (-0.319), while the non significant negative association for individual fruit weight (-0.178) and length of fruit (-0.110) and non significant positive association with number of branches/plant (0.114) and diameter of fruit (0.133). Niranjan and Mishra (2003) reported that days to flowering, yield/plant, number of fruits/plant, fruit length, fruit weight, plant height and number of branches/plant had positive and significant association among each other at both levels. Dhankhar and Dhankhar (2002) reported that number of days to 50% flowering had positive association with yield and number of fruits per plant had positive relationship with number of days to 50% flowering.

4.3.2 Number of branches/plant

Number of branches/plant of okra lines showed significant positive association with diameter of fruit (0.196) and non significant positive association was recorded for Days to 1st flowering (0.114), individual fruit weight (0.002) and yield/plant (0.020), whereas negative non significant association was recorded for number of internodes/plant (-0.048), plant height (-0.051), length of fruit (-0.016), number of fruits/plant (-0.033) and yield/hectare (-0.007). Niranjan and Mishra (2003) reported that yield/plant, number of fruits/plant, fruit length, fruit weight, plant height and number of branches/plant had positive and significant association among each other at both levels.

Table 5. Correlation matrix of different yield contributing characters and yield of okra as influenced by different lines

Okra lines	Days to 1st flowering	Number of branches/Plant	Number of internodes/ plant	Plant height (m) at last harvest	Individual fruit weight (g)	Length of fruit (cm)	Diameter of fruit (cm)	Number of fruits/ plant	Yield/ plant (g)	Yield/hectare (ton)
Days to 1st flowering	1.00									
Number of branches/plant	0.114	1.00								
Number of internodes/ plant	-0.206*	-0.048	1.00							
Plant height at last harvest	-0.286**	-0.051	0.621**	1.00						
Individual fruit weight	-0.178	0.002	0.321**	0.418**	1.00					
Length of fruit	-0.110	-0.016	0.157	0.259**	0.381**	1.00				
Diameter of fruit	0.133	0.196*	0.301**	0.330**	0.111	0.082	1.00			
Number of fruits/plant	-0.251**	-0.033	0.356**	0.599**	0.200	0.274**	0.476**	1.00		
Yield/plant	-0.258**	0.020	0.418**	0.669**	0.663**	0.397**	0.395**	0.819**	1.00	
Yield/hectare	-0.319**	-0.007	0.390**	0.655**	0.629**	0.369**	0.389**	0.824**	0.968**	1.00

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

4.3.3 Number of internodes/plant

Significant positive association was recorded for number of internodes/plant of okra lines with plant height (0.621), individual fruit weight (0.321), diameter of fruit (0.301), number of fruits/plant (0.356), yield/plant (0.418) and yield/hectare (0.390), whereas non significant positive association was recorded for length of fruit (0.157). On the other hand, negative significant association was recorded for Days to 1st flowering (-0.206) and negative non significant association was recorded for number of branches/plant (-0.048).

4.3.4 Plant height at last harvest

Plant height of okra lines showed significant positive association with number of internode/plant (0.621), individual fruit weight (0.418), length of fruit (0.259), diameter of fruit (0.330), number of fruits/plant (0.599), yield/plant (0.669) and yield/hectare (0.655). On the contrary, negative significant association was recorded for Days to 1st flowering (-0.286) and negative non significant association was recorded for number of branches/plant (-0.051). Niranjan and Mishra (2003) reported that yield/plant, number of fruits/plant, fruit length, fruit weight, plant height and number of branches/plant had positive and significant association among each other at both levels. Saifullah and Rabbani (2010) reported that plant height showed positive direct effect on fruit yield per plant.

4.3.5 Individual fruit weight

Significant positive association was recorded for individual fruit weight of okra lines with number of internodes/plant (0.321), plant height (0.418), length of fruit (0.381), yield/plant (0.663) and yield/hectare (0.629), while non significant positive association was recorded with number of branches/plant (0.002), diameter of fruit (0.111) and number of fruits/plant (0.200), whereas non negative significant association was recorded for Days to 1st flowering (-0.178). Niranjan and Mishra (2003) reported that yield/plant, number of fruits/plant, fruit length, fruit weight, plant height and number of branches/plant had positive and significant association among each other at both levels.

4.3.6 Length of fruit

Data revealed that significant positive association for length of fruit of okra lines with plant height (0.259), individual fruit weight (0.381), number of fruits/plant (0.274), yield/plant (0.397) and yield/hectare (0.369), while non significant positive association was recorded with number of internodes/plant (0.157), diameter of fruit (0.082). On the other hand, non negative significant association was recorded for Days to 1st flowering (-0.110) and number of branches/plant (-0.016). Niranjan and Mishra (2003) reported that yield/plant, number of fruits/plant, fruit length, fruit weight, plant height and number of branches/plant had positive and significant association among each other. Patil *et al.* (1996) reported that length of fruit showed positive direct effect on fruit yield per plant.

4.3.7 Diameter of fruit

From the data it was found significant positive association for diameter of fruit of okra lines with number of branches/plant (0.196), number of internodes/plant (0.301), plant height (0.330), number of fruits/plant (0.476), yield/plant (0.395) and yield/hectare (0.389), while non significant positive association was recorded with Days to 1st flowering (0.113), individual fruit weight (0.111), length of fruit (0.082). Saifullah and Rabbani (2010) reported that diameter of fruit showed positive direct effect on fruit yield per plant.

4.3.8 Number of fruits/plant

Significant positive association was recorded for number of fruits/plant of okra lines with number of internodes/plant (0.356), plant height (0.599), length of fruit (274), diameter of fruit (0.476), yield/plant (0.819) and yield/hectare (0.824), while non significant positive association was recorded with individual fruit weight (0.200). On the other hand, significant negative association was recorded for Days to 1st flowering (-0.251) and non significant negative association with number of branches/plant (-0.033). Adeniji and Aremu (2007) observed a positive correlation was recorded for number of pods/plant and seed weight, height at maturity, ridges/pod and seeds/ridge. Hazra and Basu (2000) reported that number of fruits per plant showed positive direct effect on fruit yield per plant.

4.3.9 Yield/plant

Yield/plant of okra lines showed significant positive association was recorded for with number of internodes/plant (0.418), plant height (0.669), individual fruit weight (0.663), length of fruit (0.397), diameter of fruit (0.395), number of fruits/plant (0.819) and yield/hectare (0.968), while the non significant positive association for number of branches/plant (0.020) and negative association for days required for flowering (-0.258). Niranjan and Mishra (2003) reported that yield/plant, number of fruits/plant, fruit length, fruit weight, plant height and number of branches/plant had positive and significant association among each other at both levels. Jaiprakashnarayan and Ravindra (2004) reported that total yield/plant was positively and significantly correlated with number of fruits/plant, average fruit weight, fruit length, plant height and number of leaves at 45 and 100 DAS, but negatively and significantly correlated with days to first fruiting.

4.3.10 Yield/hectare

Data revealed that significant positive association for yield/hectare of okra lines with number of internodes/plant (0.390), plant height (0.655), individual fruit weight (0.629), length of fruit (0.369), diameter of fruit (0.389), number of fruits/plant (0.824) and yield/plant (0.824), while the significant negative association for yield/hectare (-0.319) and non significant negative association with number of branches/plant (-0.007). Saifullah and Rabbani (2010) reported that that fruit yield/plant had positive significant correlations with internodes/plant, length and diameter of fruit, fruits/plant, average weight of fruit and seeds/fruit but fruit yield had significant negative correlation with days to first flowering. Bhalekar *et al*. (2005) reported significant association of yield with plant height, number of branches/plant, number of nodes/plant, internodal length, days to 50% flowering, first fruiting node, number of fruits/plant, fruit diameter, number of locules/fruit, fruit length, tip length of fruit, fruit weight. Mahaveer *et al*. (2010) reported that fruit yield was positively and significantly associated with plant height, number of branches, internode length, fruit weight and number of fruits/plant.

4.4 Path Co-efficient Analysis

Path co-efficient analysis denotes the components of correlation co-efficient within different traits into the direct and indirect effects and indicates the relationship in more meaningful way. Path co-efficient were analyzed using the genotypic correlation only. The results of the path co-efficient using genotypic correlation are presented in Table 6.

4.4.1 Yield/hectare *vs* Days to 1st flowering

Path analysis revealed that Days to 1st flowering had negative direct effect (-0.133) on yield/hectare (Table 6). It showed negligible positive indirect effect through number of branches/plant, plant height, individual fruit weight, length of fruit, number of fruits/plant and yield/plant. Days to 1st flowering showed negative indirect effect through number of internodes/plant and diameter of fruit. Dhankhar and Dhankhar (2002) reported that the number of fruits/plant had positive relationship with number of days to 50% flowering.

4.4.2 Yield/hectare *vs* number of branches/plant

The number of branches/plant had negative direct effect (-0.248) on yield/hectare (Table 6). It showed negligible positive indirect effect through Days to 1st flowering, number of internodes/plant, individual fruit weight, diameter of fruit, number of fruits/plant and yield/plant. Number of branches/plant showed negative indirect effect through plant height and length of fruit. Dhankhar and Dhankhar (2002) reported that the number of fruits/plant had positive relationship with number of branches/plant.

4.4.3 Yield/hectare *vs* number of internodes/plant

Path analysis revealed that number of internodes/plant had positive direct effect (0.245) on yield/hectare (Table 6). It showed negligible positive indirect effect through number of branches/plant, plant height, individual fruit weight, diameter of fruit, number of fruits/plant and yield/plant. Number of internodes/plant showed negative indirect effect through Days to 1st flowering and length of fruit.

Table 6. Partitioning of genetic correlation into direct (bold) and indirect effects of yield contributing characters on yield of 34 okra lines

Characters	Days to 1st flowering	Number of branches/ Plant	Number of internodes/ plant	Plant height (m) at last harvest	Individual fruit weight (g)	Length of fruit (cm)	Diameter of fruit (cm)	Number of fruits/ plant	Yield/ plant (g)	Yield/ hectare (ton)
Days to 1st flowering	**-0.133**	0.029	-0.386	0.033	0.147	0.063	-0.257	0.094	0.091	0.319
Number of branches/Plant	0.156	**-0.248**	0.101	-0.114	0.085	-0.155	0.015	0.134	0.019	0.007
Number of internodes/plant	-0.177	0.132	**0.245**	0.068	0.022	-0.157	0.198	0.027	0.032	0.390
Plant height at last harvest	0.142	0.077	0.019	**0.137**	-0.134	0.045	-0.123	0.130	0.362	0.655
Individual fruit weight	-0.111	-0.059	0.327	0.165	**0.104**	0.078	-0.184	0.075	0.234	0.629
Length of fruit	0.038	0.044	-0.016	0.138	-0.072	**0.088**	-0.135	0.123	0.161	0.369
Diameter of fruit	0.109	0.092	-0.145	0.236	-0.123	0.045	**0.122**	0.008	0.045	0.389
Number of fruits/plant	0.024	-0.135	0.169	0.248	-0.088	0.075	0.143	**0.095**	0.293	0.824
Yield/plant	0.167	0.182	0.067	0.109	0.099	-0.133	0.078	0.035	**0.364**	0.968

Residual effect = 0.3461

4.4.4 Yield/hectare *vs* plant height

Path analysis showed that plant height had positive direct effect (0.137) on yield/hectare (Table 6). It showed negligible positive indirect effect through Days to 1st flowering, number of branches/plant, number of internodes/plant, plant height, length of fruit, number of fruits/plant and yield/plant. Plant height showed negative indirect effect through individual fruit weight and diameter of fruit.

4.4.5 Yield/hectare *vs* individual fruit weight

The path analysis revealed that individual fruit weight had positive direct effect (0.104) on yield/hectare (Table 6). It showed negligible positive indirect effect through number of internodes/plant, plant height, length of fruit, number of fruits/plant and yield/plant. Individual fruit weight showed negative indirect effect through Days to 1st flowering, number of branches/plant and diameter of fruit. Niranjan and Mishra (2003) reported that fruit weight exerted the highest positive direct effect (0.507) and the highest genotypic correlation value (0.975) on fruit yield/plant.

4.4.6 Yield/hectare *vs* length of fruit

From the path analysis we found that length of fruit had positive direct effect (0.088) on yield/hectare (Table 6). It showed negligible positive indirect effect through days to 1^{st} flowering, number of branches/plant, plant height, number of fruits/plant and yield/plant. Length of fruit showed negative indirect effect through number of internodes/plant, individual fruit weight and diameter of fruit.

4.4.7 Yield/hectare *vs* diameter of fruit

The diameter of fruit had positive direct effect (0.122) on yield/hectare (Table 6). It showed negligible positive indirect effect through days to 1^{st} flowering, number of branches/plant, plant height, length of fruit, number of fruits/plant and yield/plant. Diameter of fruit showed negative indirect effect through number of internodes/plant and individual fruit weight. Kamal *et al*. (2003) reported that Path coefficient analysis revealed width of fruit had high positive direct effect on yield/plant indicating that this character may be given higher emphasis while making selection for crop yield improvement.

4.4.8 Yield/hectare *vs* number of fruits/plant

Findings of path analysis revealed that number of fruits/plant had positive direct effect (0.095) on yield/hectare (Table 6). It showed negligible positive indirect effect through days to 1st flowering, number of internodes/plant, plant height, length of fruit, diameter of fruits and yield/plant. Number of fruits/plant showed negative indirect effect through number of branches/plant and individual fruit weight. Dhankhar and Dhankhar (2002) reported that number of fruits/plant had the highest direct effects on fruit yield. Kamal *et al*. (2003) reported that number of fruits/plant had high positive direct effect on yield/plant. So during crop improvement this characters should be taken under deep consideration.

4.4.9 Yield/hectare *vs* yield/plant

It was revealed that yield/plant had positive direct effect (0.364) on yield/hectare (Table 6). It showed negligible positive indirect effect through days to 1st flowering, number of branches/plant, number of internodes/plant, plant height, diameter of fruits and number of fruits/plant. Yield/plant showed negative indirect effect through length of fruit. Dhankhar and Dhankhar (2002) reported that number of fruits/plant and days to 50% flowering had the highest direct effects on fruit yield. Niranjan and Mishra (2003) reported that fruit weight, number of seeds/fruit, fruit length, number of fruits/plant and number of branches/plant had high direct contribution towards yield. Subrata *et al*. (2004) reported that path coefficient analysis with partitioning of phenotypic correlation revealed that number of fruits/plant and fruit weight had positive and high direct effect on fruit yield, indicating their importance as reliable selection criteria for improvement of yield in okra.

4.5 Genetic Diversity

Study of genetic diversity among 34 lines of okra assessed through Mahalanobis' D^2 statistics which has been discussed below:

Mahalanobis D^2 statistics was used to measure the degree of diversification among the lines. Using this technique, grouping of lines was done in four clusters where okra lines grouped together were less divergent than the ones placed in different clusters based on yield performance. The clusters separated by greatest statistical distance exhibited maximum divergence. Composition of different clusters with their corresponding lines and their number are shown in Table 7. Cluster I was the largest cluster comprising of 14 lines followed by cluster II with 10 lines and the cluster IV contains 6 lines and the cluster IV contains 4 lines. The most promising lines AE 018, AE 050 and AE 212 were belong to cluster I.

Table 7. Clustering pattern of 34 okra lines by Tocher's method

Cluster	Members	Okra lines
I	14	AE 014, AE 015, AE 018, AE 019, AE 020, AE 026, AE 028, AE 029, AE 050, AE 137, AE 146, AE 147, AE 212 and BARI Dherosh 1
II	10	AE 012, AE 016, AE 017, AE 022, AE 023, AE 024, AE 025, AE 030, AE 031 and AE 032,
III	4	AE 001, AE 011, AE 021and AE 053
IV	6	AE 003, AE 005, AE 013, AE 027, AE 051 and AE 052

The inter and intra-cluster distance were presented in Table 8. The results showed that the inter-cluster distances between the different clusters of okra lines differed widely. The inter-cluster distances were larger than the intra-cluster distance suggesting wider genetic diversity among the okra lines of different groups.

Table 8. Average intra (bold) and inter-cluster D^2 values of 4 clusters for 34 okra lines formed by Torcher's method

Cluster	I	II	III	IV
I	**0.2013**			
II	7.034	**0.4809**		
III	13.288	6.324	**0.0430**	
IV	3.409	5.051	10.744	**0.3117**

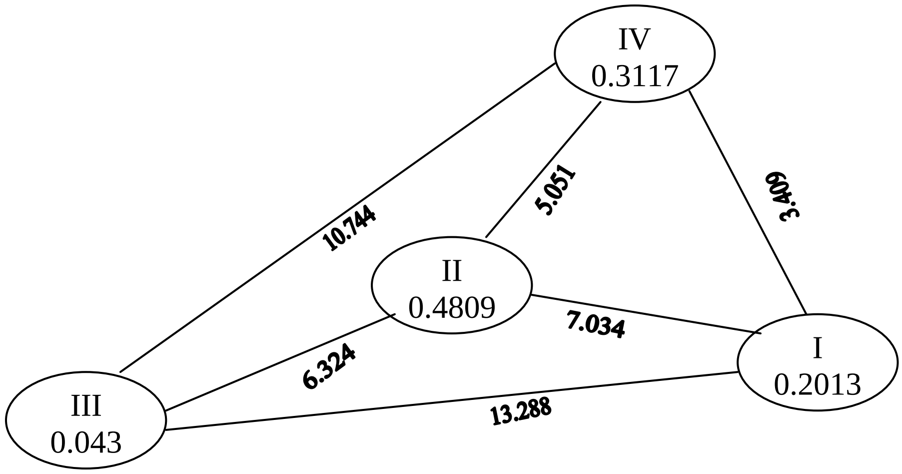

Figure 1. Intra and inter-cluster distance between different cluster

The highest inter-cluster distance was 13.288 between cluster I and III followed by cluster III and IV and moderate inter-cluster distance was 7.034 between cluster I and II followed by cluster II and III (6.324), minimum inter-cluster distance was 3.409 between cluster I and IV followed by cluster II and IV (5.051) (Figure 1). The maximum value of inter cluster distance indicated that the lines belonging to cluster I was far away from those of cluster III. Similarly, the higher cluster distance between cluster III and IV indicated that the okra lines belonging to each pair of cluster were more diverse. The moderate inter cluster distance between cluster I and II followed by cluster II and III indicate moderate genetic divergence among the lines. The minimum inter cluster distance between cluster I and IV followed by cluster II and IV indicate minimum genetic divergence among the lines.

Higher inter and intra-cluster distances indicated that higher genetic diversity among lines between and within clusters respectively. The minimum inter and intra-cluster distances indicated that the lines are closed of two clusters and within the cluster also.

CHAPTER V

SUMMARY AND CONCLUSION

In consideration the mean performance of yield contributing characters and yield, data revealed that the highest days required for 1st flowering (51.67) was observed in AE 032, while the lowest days (41.00) was recorded in AE 018, AE 024 and AE 030. The maximum number of branches per plant (4.17) was recorded in AE 022, whereas the minimum number (1.33) was found in AE 052 and AE 016. The maximum number of internodes per plant (34.23) was attained in AE 050 and the minimum number (16.10) in AE 014. The longest plant (1.75 m) was observed in AE 050, while the shortest plant (0.84 m) was recorded in AE 053. The highest individual fruit weight (20.53 g) was found in AE 026, while the lowest weight (11.80 g) was recorded in AE 053. The highest length of fruit (16.57 cm) was recorded in AE 025, while the lowest length of fruit (12.03 cm) was found in AE 023. The highest diameter of fruit (1.71 cm) was observed in AE 018, while the lowest length of fruit (1.29 cm) was recorded in AE 053. The maximum number of fruit (40.33) was found in AE 050, whereas the minimum number of fruits per plant (21.00) was observed in AE 013. The highest yield per plant (701.67 g) was observed in AE 018 and the lowest yield per plant (274.17 g) was attained in AE 003 lines. The highest yield per hectare (23.85 ton) was observed in AE 018, whereas the lowest yield per hectare (9.32 ton) was recorded in AE 003. The highest YVMV infestation (91.00%) was recorded in AE 032, again the lowest infestation (2.67%) in AE 018 lines.

In consideration of days required for flowering, phenotypic variation (16.11) was higher than the genotypic variance (10.66) that supported by narrow difference between phenotypic (4.01%) and genotypic (3.27%) co-efficient of variation with high heritability (66.18%) and moderate genetic advance (7.01%) and moderate genetic advance in percentage of mean (15.21). Phenotypic variation (0.86) was higher than the genotypic variance (0.69) with narrow difference phenotypic (0.93%) and genotypic (0.83%) co-efficient of variation for number of branches per plant with high heritability (79.48%) attached with low genetic advance (1.95%) and high genetic advance in percentage of mean (75.77). Number of internodes per plant showed phenotypic variation (19.86) was higher than the genotypic variance (17.21) supported by narrow difference between phenotypic (4.46%) and genotypic (4.15%) co-efficient of variation and high heritability (86.67%) in number of internodes per plant attached with high genetic advance (10.20%) and high genetic advance in percentage of mean (42.98). Plant height in terms of phenotypic variation (0.05) was higher than the genotypic variance (0.04) supported by narrow difference between phenotypic (0.22%) and genotypic (0.20%) co-efficient of variation with heritability (81.76%) for plant height attached with low genetic advance (0.48%) and high genetic advance in percentage of mean (38.85%). Individual fruit weight of okra in respect of phenotypic variation (5.50) was higher than the genotypic variance (4.79) that supported by narrow difference between phenotypic (2.35%) and genotypic (2.19%) co-efficient of variation with high heritability (87.04%) for individual fruit weight attached with moderate genetic advance (5.39%) and high genetic advance in percentage of mean (35.12).

Length of fruit in terms of phenotypic variation (1.56) was higher than the genotypic variance (1.00) with narrow difference between phenotypic (1.25%) and genotypic (1.00%) co-efficient of variation and high heritability (64.17%) for length of fruit attached with low genetic advance (2.12%) and moderate genetic advance in percentage of mean (15.24%). Phenotypic variation (0.02) was higher than the genotypic variance (0.01) supported by narrow difference between phenotypic (0.14%) and genotypic (0.11%) co-efficient of variation for diameter of fruit with high heritability (63.16%) attached with lowest genetic advance (0.23%) and moderate genetic advance in percentage of mean (15.28). Number of fruits per plant in terms of phenotypic variation (28.67) was higher than the genotypic variance (24.74) supported by narrow difference between phenotypic (5.35%) and genotypic (4.97%) co-efficient of variation with high heritability (86.29%) for number of fruits per plant attached with moderate genetic advance

(12.20%) and high genetic advance in percentage of mean (41.90). Phenotypic variation (14054.64) was higher than the genotypic variance (12840.20) in terms of fruit yield per plant which was supported by narrow difference between phenotypic (118.55%) and genotypic (113.31%) co-efficient of variation and high heritability (91.36%) with high genetic advance (285.93%) and high genetic advance in percentage of mean (63.64). Yield per hectare in terms of phenotypic variation (14.43) was higher than the genotypic variance (13.16) which was supported by narrow difference between phenotypic (3.80%) and genotypic (3.63%) co-efficient of variation and high heritability (91.17%) for fruit yield per hectare attached with moderate genetic advance (9.14%) and high genetic advance in percentage of mean (60.49).

Data revealed that significant positive association for yield per hectare of okra lines with number of internodes per plant (0.390), plant height (0.655), individual fruit weight (0.629), length of fruit (0.369), diameter of fruit (0.389), number of fruits per plant (0.824) and yield per plant (0.824), while the significant negative association for yield per hectare (-0.319) and non significant negative association with number of branches per plant (-0.007). Path analysis revealed that days required for 1st flowering had negative direct effect (-0.133), number of branches per plant had negative direct effect (-0.248), number of internodes per plant had positive direct effect (0.245), plant height had positive direct effect (0.137), individual fruit weight had positive direct effect (0.104), length of fruit had positive direct effect (0.088), diameter of fruit had positive direct effect (0.122), number of fruits per plant had positive direct effect (0.095) and yield per plant had positive direct effect (0.364) on yield per hectare.

The clusters separated by greatest statistical distance exhibited maximum divergence. Cluster I was the largest cluster comprising of 14 lines followed by cluster II with 10 lines. Cluster II had the highest intra-cluster distance (0.4809) followed by cluster IV (0.3117). Cluster III had the lowest intra cluster distance (0.0430) followed by cluster I (0.2013).

Number of internodes per plant, plant height, individual fruit weight, length of fruit, diameter of fruit, number of fruits per plant and yield per plant had positive direct effect on yield per hectare, whereas days required to 1st flowering and number of branches per plant had negative direct effect on yield per hectare. So, all the traits except days required to 1st flowering and number of branches per plant contributed directly for higher yield of okra.

From the above study it is concluded that number of fruit per plant was highest in AE 050 (40.33) and followed by AE 18 (38.33) and AE 212 (37.33). Yield per plant was highest in AE 18 (701.67 g) and followed by AE 050 (695.07 g) and BARI Dherosh-1 (693.93 g). It was evident that average yield per hectare was highest in AE 018 (23.85 ton) followed by AE 050 (23.63 ton) and AE 212 (21.21 ton).Yellow Vain Mosaic Virus infestation was lowest in AE 18 (2.67%) followed by AE 050 (3.0%) and BARI Dherosh-1 (3.70%).

Genetic parameters like the heritability (%), yield per plant 91.36 g was highest followed by yield ton per ha (91.17), individual fruit weight (87.04) and number of internodes per plant (86.67). Genetic Advance in percentage of mean number of branches per plant was highest (75.77) that was followed by yield per plant (63.64) and yield ton per hectare (60.49).

In case of correlation matrix for different yield contributing characters yield per hectare was highest and it was 0.968 followed by yield per plant 0.819 and number of internodes per plant 0.621. All these parameters were significant at 5% level of Probability.

From Mahalanobis D^2 statistics for ten characters we found that four clusters were formed cluster I contains the highest number of lines (14) followed by cluster II (10), cluster IV (06) and cluster III (04). The highest intra-cluster distance was recorded in cluster II (0.4809) followed by cluster IV (0.3117). The lowest intra-cluster distance was observed in cluster III (0.0430) followed by cluster I (0.2013). The intra-cluster distances indicated that the lines within the cluster were less diverse. The highest inter-cluster distance was observed between cluster

I and III (13.288) followed distance between cluster III and IV (10.744). The lowest inter-cluster distance was observed between cluster I and IV (3.409) followed by the distance between the cluster II and IV (5.051).

Conclusion:

1. Phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the yield contributing traits.
2. Correlation analysis revealed that the characters number of branches per plant, number of internodes per plant, plant height (m) at last harvest, individual fruit weight(g), length of fruit (cm) and diameter of fruits per plant had highly positive correlation with yield per plant.
3. Path analysis assessed that all the characters except length of fruit (-0.133cm) had positive direct effect on yield per plant
4. Multivariate analysis showed that the lowest intra-cluster distance indicated the lines within the cluster less diverse. The highest inter-cluster distance indicated the lines between the clusters were more diverse.

Finally, it is concluded that considering all the parameters AE 018, AE 050 and AE 212 were selected superior as well as high yield and tolerant to YVMV infestation. These lines may be recommends for further trail as new variety(s) of okra.

REFERENCES

Adeniji, O. T. and Aremu, C. O. 2007. Interrelationships among characters and path analysis for pod yield components in West African Okra (*Abelmoschus caillei* (A. Chev) Stevels). *J. Agron*., **6**(1): 162-166.

Ajmal, H. R., Rattan, R. S. and Saini, S. S. 1979. Correlation and path coefficient analysis in okra (*Abelmoschus esculentus* L.). *Haryana J. Hort. Sci*., **8**: 58-63.

Akotkar, P. K., De, D. K. and Pal, A. K. 2010. Genetic variability and diversity in okra (*Abelmoschus esculentus* L. Moench). *Elec. J. Plant Breed*., **1**(4): 393-398.

Allard, R. W. 1960. Principles of Plant Breeding. John Willey and Sons, Inc, New York. p. 36.

Anonymous. 1993. Pod development and germination studies in okra (*Abelmoschus esculentus* L. Moench). *Indian J. Agril. Sci*., **41**(10): 852-856.

Arora, S. K. 2000. Diallel analysis for combining ability studies in okra (*Abelmoschus esculentus* L.). *Punjab Hort. J*., **33**(1-2): 116-122.

Arumuga, M. R., Muthukrishanan, C. R. and Irulappan, I. 1981. Association of metric traits in bhindi. *South Indian Hort*., **29**: 1-3.

Azad, A. K. 1999. Genetic diversity of jackfruit in Bangladesh and development of propagation methods. Ph. D. thesis, University of Southamptan, U.K. p. 3

BBS. 2010. Monthly Statistical Bulletin of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning. Government of the People's Republic of Bangladesh, Dhaka. p. 47.

Bendale, V. W., Kadam, S. R., Bhave, S. G., Mehta, J. L. and Pethe, U. B. 2003. Genetic variability and correlation studies in okra. *Orissa J. Hort*., **31**(2): 1-4.

Bhalekar, S. G., Nimbalkar, C. A. and Desai, U. T. 2005. Correlation and path analysis studies in okra. *J. Maharashtra Agril. Univ*., **30**(1): 109-112.

Burton, G. W. 1952. Quantitative inheritance in grass pea. Proceedings of the 6th *Internl. Grassland Congr.*, **1**: 277-283.

Chandra, D. K. Singh, P. and Panda, P. K. 1997. Genetic analysis of certain quantitative traits in okra (*Abelmoschus esculentus* L. Moench.). *Adv. Plant Sci*., **10**(2): 179-184.

Chandra, D. K. Singh, P., Panda, P. K. and Deo, C. 1998. Inheritance of pod yield and its components in okra (*Abelmoschus esculentus* L. Moench.). *Orissa J. Hort*., **26**(2): 18-22.

Changani, N. B. and Shukla, P. T. 1990. Estimates of gene effects in okra (*Abelmoschus esculentus* L. Moench.). *Indian J. Agric. Res*., **24**(4): 198-204.

Chaudhary, D., Kumar, R., Vidyasagar, J. and Sharma, S. K. 1991. Line × tester analysis of combining ability in okra (*Abelmoschus esculentus* L. Moench.). *South Indian Hort*., **39** (6): 337-340.

Comstock, K. and Robinson, P. R. 1952. Estimation of genetic advance. *Indian J. Hill*., **6**(2): 171-174.

Dash, G. B. and Mishra, P. K. 1995. Variation and character association of fruit yield and its component characters in okra. *Current Agril. Res*., **8**(3-4): 123-127.

Dewey, D. R. and Lu, K. H. 1959. A correlation and path coefficient analysis of components of creast wheat grass seed production. *Agron. J. Hort*., **57**(4): 342-346.

Dhankhar, B. S. and Dhankhar, S. K. 2002. Correlation and path analysis in okra (*Abelmoschus esculentus* L. Moench). *Haryana J. Hort. Sci*., **31**(3/4): 294.

Dhillon, T. S. 1992. Response of selection for resistance to yellow vein mosaic virus in okra (*Abelmoschus esculentus* L. Moench.). A Ph. D. dissertation, Punjab Agril. Univ, Ludhiana, India. p. 251.

Edris, K. M., Islam, A. T. M. T., Chowdhury, M. S. and Haque, A. K. M. M. 1979. Detailed Soil Survey of Bangladesh, Dept. Soil Survey, Govt. People's Republic of Bangladesh. p. 118.

FAO. 1988. Production Year Book. Food and Agricultural Organizations of the United Nations. Rome, Italy. 190-193.

Gandhi, H. T., Yadav, M. D. and Navale, P. A. 2002. Character association and path analysis in okra. *J. Maharashtra Agril. Univ*., **27**(1): 110-112.

Geneif, A. H. D. A. 1984. Tapping natural genetic variability of okra in the Sudan. *Acta Hort*., **143**: 175-182.

Gill, S. S., Geeta B., Gill, B. S. and Arora, S. K. 1997. Morphological variation and characterization of okra. *Crop Improv*., **24**(1): 69-73.

Golakia, P. R. and Maken, V. G. 1992. D^2 analysis in *Virginia runner* groundnut genotypes. *Indian J. Genet*., **52**(3): 252-256.

Gomez, K. A. and Gomez, A. A. 1984. Statistical Procedure for Agricultural Research (2nd edn.). Int. Rice Res. Inst., A Willey Int. Sci., pp. 28-192.

Hazra, P. and Basu, D. 2000. Genetic variability, correlation and path analysis in okra. *Ann. Agril. Res*., **21**(3): 452-453.

Hoque, M. and Hazarika, G. N. 1996. Genetic architecture of yields and yield contributing characters in okra (*Abelmoschus esculentus* L. Moench.). *J. Agril. Sci*., **9**(1): 72-75.

Hussein, H. A., Farghali, M. A., E1-Zawahry, A. M. and Damarany, A. M. 1994. Growth, yield and nematode reaction in some okra accessions. *J. Agril. Sci*., **25**: 113-129.

Jaiprakashnarayan, R. P. and Ravindra, M. 2004. Correlation and path analysis in okra [*Abelmoschus esculentus* (L.) Moench]. *Indian J. Hort*., **61**(3): 232-235.

Jawili, M. E. and Rasco Jr. E. T., 1990. Combining ability, heterosis and correlation among plant and yield characters in okra (*Abelmoschus esculentus* L. Moench.). *The Philippine Agril*., **73**(1): 75-88.

Johnson, H. W., Robinson, H. F. and Comstock, R. E. 1955. Estimation of genetic and environmental variability in soybeans. *Agron. J*., **47**: 314-318.

Kamal, R. V., Yadav, J. R., Singh, B., Tiwari, S. K. and Singh, S. K. 2003. Correlation and path coefficient analysis in okra (*Abelmoschus esculentus* L. Moench). *Plant Arc*., **3**(2): 299-302.

Kaul, T. G. and Peter, K. V. 1978. Correlation and path co-efficient analysis of components of earliness, pod yield and seed yield in okra. *Indian J. Agril. Sci*., **48**: 459-463.

Mahaveer, K., Gangappa, E. and Satish, R. G. 2010. Correlation and path coefficient analysis of yield and yield components in okra (*Abelmoschus esculentus* L. Moench.). *Envir. Ecol*., **28**(4A): 2625-2628.

Martin, F. W. and Rhodes, A. M. 1983. Seed characteristics of okra and related *Abelmoschus* species. *Plant Food Human Nutri*., **33**(1): 41-49.

Mishra, R. S. and Chhonkar, V. S. 1979. Genetic divergence in okra. *Indian J. Agric. Sci*., **49**: 244-246.

Niranjan, R. S. and Mishra, M. N. 2003. Correlation and path coefficient analysis in okra (*Abelmoschus esculentus* L. Moench). *Prog. Hort*., **35**(2): 192-195.

Partap, P. S. and Dhankhar, B. S. 1980. Combining ability studies in okra (*Abelmoschus esculentus* L. Moench.). *Genetica Agraria*., **34**(1-2): 67-73. [Cited from cab abstract].

Partap, P. S., Dhankhar B. S. and Pandita, M. L. 1980. Genetic of yield and its components in okra. *Indian J. Agric. Sci*., **50**(4): 320-325.

Patil, Y. B. Madalageri, B. B., Biradar, B. D. and Mosamani R. M. 1996. Variabilities studies in okra (*Abelmoschus esculentus* L. Moench). *Karnataka J. Agric. Sci*., **9**(2): 289-293.

Paudyal, K. P. 1999. Genetic diversity of pommelo (*Citrus grandis* L. Osbeck) in Nepal and improvement of propagation methods. A. Ph. D. thesis. University of Southampton. U. K. P. 309.

Perdosa, J. F. Mzubutti, A., Casali, V. W. D. and Campos, J. P. D. 1983. The morphological characters of okra introductions. *Hort. Brasileia*. **1**(1): 14-23. [Cited from cab abstract].

Poshiya, V. K. and Vashi, P. S. 1995. Combining ability analysis over environments in okra (*Abelmoschus esculentus* L. Moench.). *Gujrat Agril. Univ. Res. J*., **20**(2): 64-68.

Purseglove, J. W. 1987. Tropical crops dicotyledons. Longman Singapore publishers (Ptv.) Ltd. p. 369.

Ramesh, P. M. Syamal, M. Singh, A. K. and Pathak, R. 1998. Line x tester analysis for combining ability in okra (*Abelmoschus esculentus* L. Moench). *Recent Hort.*, **4**: 127-132.

Ramphall, C. and Gill, H. S. 1990. Demand and supply of vegetables and pulses in South Asia. In: Vegetable research and development in South Asia: Proceeding of a workshop held at Islamabad, Pakistan, 24-29 September, 1990. S Shanmugasundaram (ed). AVRDC publication no. 90-331. AVRDC, Tainan, Taiwan. P. 123-145.

Rao, T. S. 1972. Note on natural variability for some qualitative and quantitative characters in okra. *Indian J. Agric. Sci*., **42**: 437-438.

Rashid, M. 1990. Effect of nitrogen and phosphorus levels on seed production of okra (*Abelmoschus esculentus* L. Moench). *Haryana J. Hort. Sci*., **9**: 3-4.

Rath, U. K. Sahu, G. S. and Mishra, R. S. 1991. Studies on genetic variability in okra. *Orissa J. Agric. Res*., **4**(1-2): 48-51.

Saifullah, M. and Rabbani, M. G. 2010. Studies on the character association and path analysis in okra (*Abelmoschus esculentus* L. Moench.). *Intl. J. Sus. Agril. Tech*., **6**(4): 10-15.

Sanjay, K., Annapurna, D. and Yadav, Y. C. 2009. Correlation coefficient and path analysis studies in okra (*Abelmoschus esculentus* L. Moench). *Annals of Hort*., **2**(2): 166-170

Sannigrani, A. K. and Chaudhury, K. 1998. Evaluation of okra cultivar for yield. *J. Agril. Forestry*. **46**(4): 1-10.

Savello, P. A., Mortin F. W., and Hill, J. M. 1980. Nutritional composition of okra seed meal. *Agril. Food Chem*., **28**: 1163-1166.

Shekhavat, A. K. S., Singh, B., Yadav, J. R. and Srivastava, J. P. 2005. Character association in okra (*Abelmoschus esculentus* L. Moench). *Plant Archives*. **5**(1): 289-291.

Shukla, A. K. Gautam, N. C., Tiwari, A. K. and Chaturvedi, A, K. 1989. Heterosis and combining ability in okra (*Abelmoschus esculentus* L. Moench.). *Veg. Sci*., **16**(2): 191-196.

Singh, D. 1983. Biometrical and genetical studies in okra (*Abelmoschus esculentus* L. Moench). A Ph. D. dissertation, Punjab Agril. Univ., Ludhiana. India. 312p.

Singh, K. Y. Kalloo, S. M. and Mohrotra, N. 1974. Genetic variability and correlation studies in bhindi (*Abelmoschus esculentus* L. Moench.). *Veg. Sci.*, **1**: 47-54.

Singh, N. 1993. Genetic studies in okra (*Abelmoschus esculentus* L. Moench.). A M. Sc. thesis, Punjab Agril. Univ., Ludhiana, India. P. 78.

Singh, N. S., Arora, K., Ghai, T. R. and Dhillon, T. S. 1996. Combining ability studies in okra (*Abelmoschus esculentus* L. Moench.). *Punjab Veg. Grower*. **31**: 6-9.

Singh, R. K. and Chaudhary, B. D. 1985. Biometrical methods in quantitatives gegetic analysis. Kalyani Publishers, New Delhi, India. p. 318.

Singh, R. K. and Chaudhury, B. D. 1985. Biometrical Method in Quantitative Genetics Analysis (rev. ed.). Kalyain Publishers, New Delhi, India, pp. 78-85.

Singh, S. P. 1986. Estimation of growth variance of yield and other characters in okra. *Agriculturist*, **30**(3): 245-248.

Singh, S. P. and G. N. Singh. 1997. Fractional diallel analysis for genetic components in okra (*Abelmoschus esculentus* L. Moench.). *Adv. Plant Sci. Res*., **5-6**: 56-60.

Solankey, S. S. and Singh, A. K. 2010. Correlation studies in okra (*Abelmoschus esculentus* L. Moench). *Asian J. Hort*., **5**(1): 70-75.

Sonia, S. 1999. Varietial performance of okra (*Abelmoschus esculentus* L.) under sub humid temperate condition of Himachal Pradesh. *South Indian Hort*., **47**(1-6): 198-199.

Subrata, S., Hazra, P. and Chattopadhyay, A. 2004. Genetic variability, correlation and path analysis in okra (*Abelmoschus esculentus* L. Moench). *Hort. J.*, **17**(1): 59-66.

Tahkur, M. K. and Arora, S. K. 1986. In: Vegetable Crops in India, (Ed. Bose, T. K. and Som, M. G.). Naya Prokash, Calcutta. p. 606.

UNDP. 1988. Land Resources Appraisal of Bangladesh for Agricultural Development. Report 2: Agro-ecological Regions of Bangladesh, FAO, Rome. p. 77.

van Hintum,T. J. L. 1995. Hierarchical approaches to the analysis of genetic diversity in crop plants. In: T. Hodgkin, A. H. D. Brown, Th. L. van Hintum and E. A. V. Morales (eds.); Core Collection of Plant Genetic Resources, John Willey and Sons, U. K. pp. 23.24.

Veeraragavathatham, D. and Irulappan, I. 1991. Combining ability analysis in certain okra (*Abelmoschus esculentus* L. Moench). hybrids and parents. *South Indian Hort*., **39**(4): 193-199.

Verma, V. D. 1993. Collecting eggplant and okra in Madhya Pradesh and Maharastra. India. IBPGR Newsletter for Asia Pacific and Oceania. **13**: 14-15.

Yamaguchi, Y. 1998. Effect of nitrogen, phosphorus and potassium on bhindi (*Abelmoschus esculentus* L. Moench). *Prog. Hort*., **10**(4): 21-30.

APPENDICES

Appendix I. Characteristics of field soil

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Olericulture Division of Horticulture Research Centre Bangladesh Agricultural Research Institute, Gazipur
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Ceata
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resources Development Institute (SRDI)

Appendix II. Monthly record of air temperature, relative humidity, rainfall, and sunshine (average) of the experimental site during the period from April to August 2011

Month	Air temperature (^0c)		Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
April, 2011	34.26	23.45	64	109	8.1
May, 2011	34.55	25.78	73	198	7.7
June, 2101	35.26	22.33	78	592	6.2
July. 2011	36.12	24.35	82	556	5.1
August, 2011	35.67	23.32	78	302	5.0

Source: Climate and Weather Division, BARI, Joydevpur, Gazipur.

Appendix III. Analysis of variance of the data on yield contributing characters and yield of okra as influenced by different lines

Source of variation	Degrees of freedom	Mean square				
		Days to 1st flowering	Number of branches/plant	Number of internodes/plant	Plant height (m) at last harvest	Individual fruit weight (g)
Replication	2	1.434	0.133	1.429	0.009	0.128
Okra lines	33	37.430**	2.234**	54.280**	0.130**	15.076**
Error	66	5.447	0.177	2.647	0.009	0.713
CV(%)		5.06	16.37	6.86	7.88	5.50

**: Significant at 0.01 level of probability;

Appendix III. Cont'd

Source of variation	Degrees of freedom	Mean square					
		Length of fruit (cm)	Diameter of fruit (cm)	Number of fruits/plant	Yield/plant (g)	Yield/hectare (ton)	YVMV Infestation (%)
Replication	2	1.241	0.011	2.649	202.236	1.638	9.024
Germplasm	33	3.569**	0.043**	78.141**	39735.048**	40.754**	2177.443**
Error	66	0.560	0.007	3.931	1214.438	1.275	8.812
CV(%)		5.38	5.78	6.81	7.76	7.47	6.43

**: Significant at 0.01 level of probability;

Plate 1. Photograph showing superior okra lines in consideration of yield and tolerant to YVMV infestation