Evaluation of Genetic Variability, Correlation Studies and Path Analysis of Okra [*Abelmoschus esculentus* (L.) Moench] Under Jabalpur Condition

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By
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2012

CERTIFICATE – I

This is to certify that the thesis entitled **"Evaluation of genetic variability, correlation studies and path analysis of okra (*Abelmoschus esculentus* L. Moench.) under Jabalpur condition"** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture(Horticulture) of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.)** is a record of the bonafide research work carried out by **Meenakshee Dwivedi** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and Director of Instruction.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published. All the assistance and help received during the course of the investigation has been acknowledged by her.

(Dr. D. P. Sharma)
Chairman Advisory Committee

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Member (Shri B. K. Verma) _____

Member (Dr. H. L. Sharma) _____

CERTIFICATE – II

This is to certify that the thesis entitled **"Evaluation of genetic variability, correlation studies and path analysis of okra (*Abelmoschus esculentus* L. Moench.) under Jabalpur condition"** submitted by **Meenakshee Dwivedi** to the Jawaharlal Nehru Krishi Vishwa Vidyalaya Jabalpur , in partial fulfillment of the requirements for the degree of Master of Science in Agriculture in Department of Horticulture, has been, after evaluation, approved by the External Examiner and by the Student's Advisory Committee after an oral examination of the same.

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Date:

Dr. D. P. Sharma

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Date:

Place: ***Meenakshee Dwivedi***

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LIST OF ABBREVIATIONS

et al	:	And others
%	:	Percentage
/	:	Per
@	:	At the rate of
^{0}C	:	Degree centigrade
cm	:	Centimeters
m	:	Meter
m^2	:	Square meter
mm	:	Millimeter
km/hr	:	Kilometer per hour
Fig.	:	Figure
Kg	:	Kilograms
N	:	North
S	:	South
E	:	East
W	:	West
g or gm	:	Gram (s)
FYM	:	Farm yard manure
ha	:	Hectare
q	:	Quintal
t	:	Tonnes
DAS	:	Days after sowing
GCV	:	Genotypic coefficient of variation
PCV	:	Phenotypic coefficient of variation

INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench] commonly Known as Bhindi is grown for its tender fruits in tropics, subtropics and warmer parts of temperate region. In India, it is cultivated in 452.5 thousand ha area with the production of 4803 thousand mt and productivity of 10.5 mt / ha and in M.P. it is cultivated in 8.80 thousand ha area with the production of 52.80 thousand tones and productivity of 6.00 t/ha (2009-2010). The major okra producing states in India are U.P., Bihar, Orissa, W.B., A.P., and Karnataka.

Okra is a polyploid, belonging to the family Malvaceae with 2n = 8x =72,144 chromosome, it is an often cross pollinated crop. In India, among fresh vegetables, sixty per cent share of export goes to okra. According to Vavilov, it was probably domesticated in the Ethopian region but according to Murdoc it is a native of West Africa. Okra cultivars are erect annual becoming woody at maturity. The plant often reaches 60 to 180 cm in height. The flower open shortly after sunrise and remain open until about noon. Petals wilt in the afternoon and usually fall the following day.

It is a hardy crop and can be grown with considerable success on a wide range of soil under variable environmental conditions. It has high nutritive value and good export potential. Apart from its use as vegetable, it also has medicinal properties. Leaves are used for preparing a medicament to reduce inflammation. It is an excellent source of Iodine for control of goiter.

Edible fresh and mature fruits contain eighty eight per cent moisture and large number of chemical components including Vit. A (88 IU), Vit. B (63 IU) and Vit. C (13 mg/100 gm). Unripe okra fruits contain 3100 calorie energy, 1.8gm protein, 90 mg calcium and 1.0 mg iron. Seed of okra (Pusa makhmali) had the highest oil content (17.3 per cent) which is a nutritious ingredient of cattle feed.

The foremost challenge to the existence of mankind has always been to produce adequate quantity of food from the available acreage to meet the requirements of ever expending world population. The rate of yield gain in crop improvement programme must match the rate of population growth so, as to mitigate the problems of malnutrition and hunger.

Nowadays, the productivity of okra shows a declining trend. Hence, developing high yielding varieties bestowed with fruits of high quantity as well as quality is of utmost importance. Selection of genotypes having the desirable fruit attributes must be performed with reliable genetic estimates. The genetic parameters like heritability and genetic advance provide a clear insight into the extent of variability and a relative measure of efficiency of selection of genotypes based on phenotype.

The possibility of improvement in any crop is depended on variability available in the crop, wider the genetic variability in trait, better the chances of improvement of it through selection. An evaluation to detect extent of variability available for the yield attributes and their heritability values is of immense help to the breeders to select the breeding methods for improvement of that trait. Hence, an attempt was made to assess the available genetic variability in okra by partitioning of overall variability into its heritable and non-heritable components based on genetic parameters like genotypic coefficient of variation, heritability and expected genetic advance.

Heritability is an index of transmissibility of a character from parents to their off springs. But heritability alone does not give true picture of genetic improvement through selection, therefore, study of genetic advance coupled with heritability are more useful in predicting the resultant effect of selection. Genetic advance gives an idea about additive nature of gene action.

Correlation and path Analysis are the important tools useful for getting information regarding association of characters. This is very helpful for plant breeder in developing a commercial variety by determining the component characters on which selection can be based for the yield improvement. These studies along with the association analysis will be more useful in the estimation of the nature and extent of direct and indirect effect of yield contributing components using path coefficient analysis.

Keeping in view of the above facts, the present study in okra entitled “Evaluation of genetic variability, correlation studies and path analysis of okra [*Abelmoschus esculentus* (L.) Monch] under Jabalpur condition” has been carried out with the following objectives :-

1. To estimate the genetic variability and heritability of genotypes.
2. To analyse correlation of yield with it’s yield contributing parameters.
3. To quantify path coefficient analysis.
4. To identify better genotypes in relation to yield under Jabalpur condition.

REVIEW OF LITRETURE

The relevant and available literature related to the various aspects of the present investigations has been discussed under the following head:

2.1 Genetic variability.

2.1.1 Mean performance

2.1.2 Coefficient of variation

2.1.3 Heritability and genetic advance

2.2 Correlation coefficient analysis

2.3 Path coefficient analysis

2.1 Genetic variability

2.1.1 Mean performance

Farghali *et al.* (1994) reported that cultivar Clemson spineless was found to have longest fruit, while Balady assint, Balady cario and Balady green had the shortest fruits. Balady red had the largest fruit diameter and Green spineless the smallest. Balady red, White velvet, Clemson spineless, Gold coast had the heaviest fruits. Balady green and Clemson spineless had the highest dry matter contents. White velvet fruits had the highest fiber content and Green velvet the lowest.

Patil *et al*. (1996) observed considerable differences for number of pods per plant and weight of pods per plant.

Sood (1999) reported that marketable fruit yield per plant varied from 154 to 467 g and yield was highest in genotypes IC-39135, IC-9856 and Panjab Padmini. IC-39135 also had the highest number of nodes per plant. LC-12 had the highest fruit weight (22.22g), followed by perfect long green (21.60g), LC-26 (21.54g), LC-11 (20.86g), and LC-16 (20.79g). Day to 50% flowering varied from 44.33to71.00 days

and IC-45791 was the earliest to flower among the genotypes. IC-14026 and IC-45796 had the highest duration of availability of edible pods (66days).

Prakash *et al.* (2001) reported that Arka Abhay was best for high seed yield per plant (62.89g), capsule length (12.64), capsule weight (15.66) and seed yield per capsule (3.71g) whereas Parbhani kranti was registered as a superior parent for number of capsule per plant (16.60) and days to first flowers (44.90). Among the F_1 hybrids, PK x Arka Abhay showed high seed yield per plant (69.28g), number of seeds per capsule (55.38), 100 seed weight (7.22g) and capsule weight (20.20g).

AL-Ghzawi *et al.* (2003) reported that the significant differences in number of fruits per plant, number of flower per plant, number of seeds per pod, seed weight per plant and pod length were recorded. Clemson gave the highest seed weight per plant. The number of pod per plant, number of seeds per pod, seed weight per plant and pod length was higher in insect pollinated plants than self-pollinated plants.

Bendale *et al.* (2003) showed a wide range of genetic variability for yield and yield-contributing characters like first flowering node, days to first harvest, pod length, pod weight, plant height, nodes per plant, inter nodal 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.

Hamed *et al*. (2003) reported that Balady green recorded the highest number of days to first flower (71.78) and number of nodes to first flower (11.31). Gold coast had the highest number of pods per main stem (8.41), plant height (131.95cm) and yield per plant (90.50g). MNH 1999 had the highest number of branches per plant (1w2.59), number of early pods per plant (7.78) and total number of pods per plant (20.93).

Kuwar *et al*. (2003) observed that the parbhani kranti had the highest leaf area per plant (18.92dm^2/m), plant height (88.22cm), dry

matter per plant (60.62g), number of fruits per plant (16.59), fruit diameter (1.47cm), fruit weight per plant (95.48g), yield per plant (6.16kg), and yield per ha. (38.04q). Arka Anamika and AKOV-97-16 had the highest fruit length (13.86cm) and number of branches per plant (4.28), respectively.

Verma *et al.* (2004) reported that the highly significant differences between genotypes were recorded for all the characters. While higher (168.33 g/plant) fruit yield was observed in JAE-12 followed by JAE-4 (165.66g/plant) whereas, lowest fruit yield was recorded in JAE-12 followed by JAE-15 (41.33g/plant). Maximum range of mean value was observed for yield per plant and minimum for branches per plant. High degree of variability was observed for branches per plant and yield per plant.

Kumar and Kumar (2005) reported that the genotype Punjab-8 had the tallest plant (89.8cm) and produced significantly high number of primary branches (2.53) as compared to other genotypes. Punjab Padmini was recorded highest seed number per fruit (46.5), seed weight per fruit (2.6g) and seed yield (30.7g/plant and 14.5q/ha). Maximum number of fruits per plant (11.6) was recorded in Arka Abhay and Punjab Padimini.

Naidu *et al* (2007) reported highly significant differences between genotypes for all the characters. While higher (221.0g/plant) fruit yield was observed in JAE-14 followed by JAE- 18 (199.5g) whereas, lowest fruit yield was noted in JAE-4 (98.0g/plant). Maximum range of mean value was observed for yield per plant and minimum for number of ridges per fruit. High degree of variability was observed for plant height, number of fruits per plant, fruit weight and fruit yield per plant.

Singh and Annapurna (2011) reported great extent of natural variation present in the various characters among the genotypes of okra suggesting good scope of improvement in economic traits through conventional breeding techniques. The characters studied were plant

height, number of branches per plant, number of days to flower, stem diameter (cm), number of leaves per plant, number of flowers per plant, number of fruits per branch, number of fruits per plant, length of fruits (cm), weight of fruits (g), diameter of fruits (cm) and yield per plant (g). Analysed data revealed that among all the genotypes Pusa Makhmali, Perkins Long Green, Parbhani Kranti, VRO-6, VRO-5 and Selection-10 gave promising results.

Senapati *et al.* (2011) recorded that the analysis of variance exhibits a wide spectrum of variability among the characters of the hybrids. The largest variability was recorded in fruit yield (58.163-125.077 q/ha) followed by plant height (138.800 -182.267 cm).

2.1.2 Coefficient of variation

Vijay and Manohar (1990) estimated high genotypic coefficient of variation for days to 50% flowering, number of effective nodes, number of branches per plant, fruit yield per plant and low genotypic coefficient of variation observed for first fruiting nodes in okra. High phenotypic coefficient of variation was observed for internodal length.

Deo *et al.* (1996) recorded high genotypic coefficient of variation for plant height, number of effective nodes, number of branches per plant, fruit yield per plant and high phenotypic coefficient of variation for plant height and number of branches per plant in okra.

Bindu *et al.* (1997) observed high genotypic coefficient of variation for plant height, fruit weight, number of effective nodes, number of branches per plant, fruit yield per plant and high phenotypic coefficient of variation was observed for plant height, number of effective nodes and number of branches per plant in okra.

Bendale *et al.* (2003) observed phenotypic variance was higher for all the 15 characters than the genotypic variance (GCV). The

number of branches per plant, yield per plant showed high GCV and PCV estimates.

Dhall *et al.* (2001) observed high genotypic coefficient of variation and high phenotypic coefficient of variation for plant height, total yield per plant, marketable yield per plant, number of fruits per plant and virus incidence.

Bali *et al.* (2004) evaluated 31 diverse genotypes of okra for yield and combining characters and noticed high phenotypic coefficient of variation as well as high genotypic coefficient of variation for seed yield per plant, number of branches per plant, internodal length and fruit yield per plant.

Sureshbabu *et al.* (2004) reported high value of genotypic coefficient of variation combined with high heritability for the characters like fruits per plant, yield per plant, number of ribs on the fruit and height of the plant.

Singh and Singh (2006) observed high genotypic coefficient of variation and phenotypic coefficient of variation for number of branches per plant, fruit yield per plant, tapering length, plant height and fruit length.

Singh *et al.* (2006) estimated high genotypic coefficient of variation and phenotypic coefficient of variation for internodal length, number of branches per plant, number of fruits per plant, number of seeds per pod and fruit yield per plant.

Narayan *et al.* (2006) observed high genotypic and phenotypic coefficient of variation for plant height at 100 days after sowing, number of branches per plant and internodal length. Moderate genotypic and phenotypic coefficient of variation was observed for number of nodes on main stem, number of nodes at first flowering and number of leaves at 100 days after sowing. Low genotypic and phenotypic coefficient of

variation was exhibited by days to first flowering and days to 50% flowering.

Singh *et al.* (2007) observed high magnitude of genotypic and phenotypic coefficient of variation for number of branches per plant, plant height, number of fruits per plant and fruit yield. Phenotypic coefficient of variation was higher than corresponding genotypic coefficient of variation.

Magar *et al.* (2009) recorded that phenotypic co-efficient of variability was higher than the genotypic ones. GCV and PCV were of higher magnitude for fruit yield per plant followed by number of fruits per plant, node at which first flower appear, plant height and fruit weight. The magnitudinal difference between PCV and GCV estimate was maximum for node at which first flower appear and number of fruits per plant suggesting influence of environment on these traits.

Shanthakumar and Salimath (2010) revealed that analysis of variance showed highly significant differences for the populations under study. The estimates of phenotypic and genotypic coefficients of variation were moderate to high for all the characters except days to first flowering, stem diameter fruit length and 100 seed weight.

Ramanjinappa *et al.* (2011) observed that the estimates of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were found to be higher for plant height and number of branches per plant.

Senapati *et al.* (2011) revealed that phenotypic coefficients of variation (PCV) were greater than genotypic coefficients of variation (GCV) in all quantitative traits due to environmental influence.

Prakash *et al.* (2011) the phenotypic variances for all the fifteen characters were found to be higher than the genotypic variance. High GCV and PCV was observed for plant height, inter-nodal length, first

flowering node, first fruit producing node, height of first flowering node, average fruit weight and number of seeds per fruit.

Thirupathi, *et al.* (2012) estimates high magnitude of genotypic coefficient of variation (>20.00 %) for number of branches per plant, total number of fruits per plant, number of marketable fruits per plant, total yield per plant (g), marketable yield per plant (g)

2.1.3 Heritability and genetic advance

Vijay and Manohar (1990) estimated high heritability for plant height, fruit weight, number of branches per plant and low genetic advance was observed for fruit length and fruit girth.

Jeypandi and Balakrishnan (1990) noticed that heritability coupled with genetic advance were highest for yield per plant and plant height.

Patel and Dalal (1992) reported high heritability estimates for yield and it's components in seven [*Abelmoschus esculentus*] genotypes and their F_1 hybrids. Pod attributes were found to have moderate heritability estimate.

Sood *et al.* (1995) observed high heritability and genetic advance for twelve characters. The node at first fruit set, plant height and nodes per plant had high heritability values coupled with high to moderate genetic advance.

Chandra *et al.* (1996) observed high estimates of heritability and genetic advance for pod yield, plant height and number of seeds per pod.

Patil *et al*. (1996) observed relatively high genetic advance for plant height, number of pods per plant and weight of pods per plant, indicative of the likely effectiveness of selection for such characters.

Bindu *et al.* (1997) reported high heritability for plant height, fruit length, fruit weight, number of effective nodes, while moderate heritability for number of branches per plant.

Panda and Singh (1997) reported high heritability estimates coupled with high genetic advance for plant height, number of pods and total pod yield per plant and suggested to improve these traits through selection schemes.

Paiva *et al.* (1998) conducted an experiment considering 11 okra cultivars and estimated high heritability for fruit length, diameter, fruit weight, plant height and number of branches per plant.

Dhall *et al.* (2001) recorded that fruit length, plant height, number of fruits per plant and virus incidence exhibited high heritability along with high genetic advance indicating the dominant gene action.

Dhankar and Dhankar (2002) reported high to moderate heritability for fruit yield, number of fruits per plant and plant height. Genetic advance was found medium to low for all traits which indicates that there is limited scope for improvement through selection procedures.

Bali *et al.* (2004) evaluated high heritability along with high genetic advance were reported for seed yield per plant, number of seeds per pod, number of fruits per plant, internodal length and total fruit yield per plant indicating the influence of additive gene effect.

Patro and Ravisankar (2004) observed high heritability for number of branches per plant, yield per plant and high genetic advance for fruit yield per plant and plant height in okra.

Verma *et al.* (2004) estimated of high heritability and genetic advance for seeds per fruit and plant height.

Indurani and Veerargavathatham (2005) noticed high heritability coupled with high genetic advance for characters such as plant height at first flower bud appearance, number of fruits per plant and yield per plant in crop.

Singh and Singh (2006) observed high heritability for days to first flowering and first fruiting, node length and high heritability coupled with high genetic advance was observed for first fruiting node length, number of branches per plant, tapering length and fruit yield per plant.

Singh *et al.* (2006) observed high heritability coupled with high genetic advance for number of seeds per pod, internodal length, number of branches per plant, fruit yield per plant, number of fruits per plant, plant height and 100 seed weight.

Naidu *et al* (2007) estimates high heritability and genetic advance in number of nodes to first flower, number of fruits per plant, number of seeds per fruit and fruit yield per plant. These characters are governed by additive gene action.

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

Sunil *et al.* (2007) observed high heritability coupled with moderate genetic advance for days to flowering, number of nodes per plant, internodal length, fruit number per plant and yield per plant. High heritability coupled with low genetic advance was observed for plant height. Low heritability coupled with high genetic advance was reported for fruit width, tapering length of fruit and low heritability with low genetic advance for fruit length in okra.

Magar *et al.* (2009) recorded heritability with high magnitude for fruit length, total fruit yield per plant indicating major role of genotype with less environmental influence.

Akotkar *et al.* (2010) reported 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.

Balakrishnan *et al.* (2010) revealed high genetic variability and high range of variation for most of the yield attributing traits. Fruit weight showed the highest heritability in broad sense for both F1 and F2 generations. High genetic advance, genetic gain and heritability were recorded for shoot borer resistance, fruit borer resistance and plant height indicated that selection can be resorted for the improvement of these characters.

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

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

Senapati *et al.* (2011) recorded high heritability estimates were obtained in fruit yield (93.92%), edible maturity (90.98%) and days to 50% flowering (89.02%) indicating that these characters might be heritable and less influenced by environment.

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

Nwangburuka *et al.(*2012) reveled that the high genotypic coefficient of variability, % broad-sense heritability and genetic advance present in traits such as plant height (26.2, 90.7, 51.5), fresh pod length (23.9, 98.5, 48.8), fresh pod width (23.9, 98.5, 48.8), mature pod length (28.6, 98.5, 52.3), branching per plant (29.3, 82.3, 54.8) and pod weight per plant (33.9, 90.0, 63.3), suggesting the effect of additive genes and reliability of selection based on phenotype of these traits for crop improvement.

Thirupathi, *et al.* (2012) recorded characters like plant height (cm), number of branches per plant, internodal length (cm), days to fifty per cent flowering, first flowering node, first fruiting node, fruit length (cm), fruit weight (g), total number of fruits per plant, number of marketable fruits per plant, total yield per plant (g), marketable yield per plant (g), yellow vein mosaic virus infestation on fruits and plants (%) having high heritability (>60.00 %) coupled with high expected genetic advance (>20.00 %) revealed that a very significant improvement is possible through selection for all these characters.

2.2 Correlation coefficient analysis

A wide range of variation in quantitative characters provides the basis for selection in plant breeding programme. The knowledge of association among the characters is useful to the breeder for improving the efficiency of selection. Correlation coefficient analysis measures the mutual relationship between plant characters and determines the component character on which selection can be made for genetic improvement of yield. Investigation regarding the presence of component and nature of association among themselves is essential and pre-requisite for improvement in yield. As such, it is necessary to estimate the correlation coefficients to aid in estimating the true association due to genetic cause. A brief review related to this aspect is being given here.

Chantana (1990) reported that yield per plant showed positive correlations with pod number per plant, mature plant height, branches per plant and nods per plant, but it was negatively correlated with plant height at first flowering.

Shukla (1990) observed that fruit yield had a significant positive correlation with number of fruits per plant, number of nods per plant and fruit length.

Mandal and Dana (1994) reported that fruit yield was significantly and positively associated with number of fruits per plant and fruit length, whereas fruit yield showed negatively association with days to 50% flowering.

Gondane *et al.* (1995) reported the number of pods per plant weight per edible part stem thickness and plant height were significantly and positively correlated with pod yield per plant while nodes showed negative correlation with number of leaves per plant, days to 50% flowering nodes to first pod and number of branches per plant.

Sood *et al.* (1995) observed correlation among all combination of twelve characters and found that nodes per plant, duration of edible pods, plant height and pod length had strong positive correlation with yield.

Dash and Mishra (1995) reported that the fruit yield per plant was positively correlated with number of branches per plant, fruit length , fruit girth, fruit weight, number of fruits per plant and seed weight per fruit.

Mahto (1996) reported that seeds per plant showed highly significant and positive correlation with almost all the characters.

Yadav (1996) found that significant and positive correlation between yield per plant and number of fruit per plant. Days to first fruiting showed significant and positive correlation with length of fruit and width of fruit. Plant height showed significant and positive association with length of fruits.

Rajani and Manju (1997) reported that nods per plant, duration of availability of edible pods. Plant height and pod length had strong positive correlation with yield.

Paiva *et al.* (1998) observed that number of fruiting nods on main stem, plant height, number of fruits and earliness were highly correlated with yield.

Hazare and Basu (2000) reported that fruit yield per plant was significantly and positively associated with plant height, whereas, days to first flowering showed negative association with number of fruits per plant.

Gandhi *et al.* (2002) reported that the dry fruit yield was highly and significantly dependent on the number of nodes per plant, inter nodal length, number of fruits per plant and yield per plant.

Niranjan and Mishra (2003) reported that in general, the genotypic correlations were higher than the corresponding phenotypic correlation for all the character combination. Fruit yield was positively and significantly correlated with edibility period of fruits, number of fruits per plant, fruit length, number of seed per fruit, fruit weight, plant height and number of branches per plant at both genotypic and phenotypic level. Associations were significant at the genotypic level only between edibility period of fruits and number of branches per plant. All character had positive and significant association among each other at both level.

Bendale *et al*. (2003) reported that the pod length, pod weight, plant height, nodes per plant and number of pods per plant were positively correlated with the yield.

Duzyaman *et al.* (2003) observed that pod weight and diameter were positively correlated with total yield pod weight and pod number per plant was highly associated with flowering behavior and pod composition in the first year. Pod weight per plant was associated with average pod weight, pod width per plant was associated with average pod weight, pod width and flesh thickness, whereas, pod number per plant was correlated with dry matter content only. Significant correlation was observed among pod weight pod width and flesh thickness.

Narayan and Mulge (2004) reported that total yield per plant was positively and significantly correlated with number of fruits per plant, average fruit weight, number of nodes on main stem, fruit length plant height (at 60 DAS and 100 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.

Patro and Ravishankar (2004) reported that fruit yield per plant showed significant and positive correlation with number of branches per plant, fruit length and fruit weight. Significant negative correlation of fruit yield per plant was recorded with plant height and number of days taken to first pod setting.

Sureshbabu *et al.* (2004) reported significant phenotypic and genotypic correlation with yield by fruit length and fruits per plant.

Subrata *et al.* (2004) reported that in 25 genotypes of okra, fruit yield had significant positive correlation with number of fruit per plant and fruit weight.

Bhalekar *et al.* (2005) observed that fruit length, internodal length, number of fruits per plant and number of branches per plant had positive and correlation with fruit yield.

Ghosh (2005) reported that fruit yield per plant recorded significantly positive correlation with fruiting span, internodal length, number of seeds per fruit, plant height at maturity and weight of fruit.

Pawar (2005) reported that the yield per plant recorded significant positive correlation with number of fruits per plant, fruit weight, fruit length and fruit girth.

Sankaran *et al.* (2005) reported that the fruit length (0.977), fruit girth (0.922), fruit weight (0.984), cured fiber (0.973), total sugar (0.875) and acidity (0.993) had higher positive correlation with the advancement of maturity.

Choudhary (2006) reported that the yield per plant showed positively significant association with number of fruits per plant, fruit weight, length of fruit, number of seeds per fruit, plant height, fruiting span, fruit girth and number of branches per plant.

Verma *et al.* (2007) reported that yield per plant had exhibited positive and significant correlation with fruits per plant, fruit weight, fruit length and fruit girth. Negative correlation was found in 100 seed weight, days to 50% flowering and days to first flowering with yield per plant.

Magar *et al*. (2009) observed that the total fruit yield per plant was significantly and positively correlated with number of fruits per plant, fruit weight and plant height.

Balakrishnan *et al.* (2010) reported that fruit yield was positively associated with number of fruits, number of internodes, fruit weight and fruit length. Shoot and fruit borer infestation recorded negative association with plant height, flowering period, fruit number, fruit yield and internodal length. Hence, selection of genotypes with short growth habit, short flowering period and short fruit length will help to minimize the shoot and fruit borer infestation.

Saifullah *et al.* (2010) calculated genotypic and phenotypic coefficient of correlation and 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. The study also indicated that the 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.

Chaukhande *et al.* (2011) reported that yield per plant exhibited positive and significant correlation with plant height, number of flowering nodes on main stem, number of fruits per plant and average weight of fruit.

Ramanjinappa *et al*. (2011) observed that fruit yield per plant showed positive and significant correlation with plant height, number of nodes per plant, number of fruits per plant and harvest index.

Senapati *et al.* (2011) exhibited that the genotypic estimates were higher than the phenotypic ones for most of the traits, indicating a strong inherited association between the characters. Fruit yield is

showed positive and significant association with number of nodes/plant, number of fruits/plant and fruit length.

Nwangburuka *et al.* (2012) reveled positive and significant phenotypic and genotypic correlation between plant height at maturity, fresh pod width, seeds per pod and pods per plant, branches per plant with seed weight per plant and pod weight per plant, suggests that selection on the basis of the phenotype of these characters will lead to high seed and pod yield in okra.

2.3 Path coefficient analysis

As number of factors is involved in correlation studies, their association becomes more complex and confusing. Under such circumstances, the path coefficient analysis help in removing the complication by measuring the direct and indirect influence of one variable upon the other by partitioning correlation coefficient into the components of direct and indirect effects. This has also an advantage to point out the true yield determinants for genetic improvement of crop.

Choudhary and Sharma (1999) reveled that the 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 coefficient value (0.975) on fruit yield per plant.

Narayan and Mulge (2004) revealed that the average fruit weight, number of nodes on main stem and number of fruits per plant had high direct effect on total yield per plant.

Sureshbabu *et al.* (2004) reported that the fruits per plant showed the highest positive direct effect on yield followed plant height, days to flower, fruit length, fruit girth, and fruits per plant.

Pawar (2005) reported that the number of fruits per plant and number of seeds per fruit were found to be contributory characters on yield per plant owing to their high direct and indirect effects for all the characters.

Verma *et al.* (2007) revealed that the number of fruits per plant had highest direct positive effect on yield per plant followed by number of nodes to first flower. The indirect effects of most of the components towards yield were either negative or low in magnitude except in case of number of nodes to first flower via plant height and fruit length, days to first flowering via days to 50% flowering, days to 50% flowering via fruit length, days to first picking via days to 50% flowering, number of fruits per plant via fruit length and plant height.

Magar *et al.* (2009) observed that the Path co-efficient study revealed that number of fruits per plant had maximum direct contribution towards total yield followed by fruit weight, plant height and days to first flowering. These important traits may be viewed in selection programme for the further improvement of Okra.

Nasti *et al.* (2010) revealed that fruit length and ten fruit weight with yield was due to their direct positive contribution. Interesting, number of fruits per plant had maximum indirect contribution via fruit length and ten fruit weight in showed positive association with yield. Fruit shape index was found negatively correlated with fruit yield but showed high direct effect towards yield.

Saifullah *et al.* (2010) observed 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. 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.

Chaukhande *et al.* (2011) observed number of fruits per plant exhibited maximum direct effect on yield per plant followed by average weight of fruit and internodal length. Thus, all this characters must be taken into consideration while selecting the genotypes for future breeding programme.

Ramanjinappa *et al.* (2011) revealed that number of fruits per plant had highest direct influence towards fruit yield per plant followed by number of seeds per fruit, average fruit weight, harvest index and number of nodes per plant. Hence, these traits may be viewed in selection program for the further improvement of okra.

Senapati *et al.* (2011) recorded that number of fruits/plant (0.242), fruit girth (0.218) and fruit length (0.058) exhibited maximum direct effects on fruit yield at phenotypic level. On the basis of above findings, it was concluded that the number of fruits per plant and fruit length would be considered for improvement of fruit yield of okra hybrid and among the genotypes, JOH 05-9 was found the most promising hybrid followed by HOK 152 and AOH-23.

MATERIAL AND METHODS

The chapter comprises the details about the materials used and the method adopted during the course of present investigation entitled “Evaluation of genetic variability, correlation studies and path analysis of okra [*Abelmoschus esculents* (L.) Moench] under Jabalpur condition” was carried out in Kharif season during the year 2011-12 at Vegetable Research Farm, Department of Horticulture, JNKVV, Jabalpur (M.P.).

3.1 Experimental site

The experiment was conducted at Vegetable Research Farm, Department of Horticulture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.).

3.1.1 Soil

The soil of the experimental field was clay loam with good drainage and uniform texture with medium NPK status.

3.1.2 Climate and weather conditions

Jabalpur is situated in ‘Kymore plateau and Satpura hills agro-climatic region of Madhya Pradesh at 23.91˚ North latitude, 79.5˚ East longitudes and on an altitude of 411.78 meters above the mean sea level. The tropic of cancer passes through the middle of the district. The Climate of the region is typically semi-arid and sub tropical having extreme winter and summer. The average annual rainfall is 1350 mm which is mostly received during June to October from South-West monsoon. The average maximum temperature is 46˚ C and minimum temperature is 6.8˚ C. The average annual relative humidity is 74%.

The meteorological parameter were recorded at Meteorological observatory Krishi Nagar, JNKVV, Jabalpur during the crop season on parameter viz., minimum and maximum temperature, sunshine hours,

rainfall in mm, number of rainy days and relative humidity are presented in Table 3.1.

Table 3.1 Metrological information (week wise) during entire crop season of the year 2011-12 at Jabalpur

Month	Week no.	Temperature (°c)		Relative humidity (%)		Wind velocity km/hr	Sun shine hours	Rain fall (mm)	No. of rainy days
		Max.	Min.	I	II				
July	27	33.1	22.8	86	61	05.7	04.9	015.2	02
	28	31.7	23.5	92	71	06.2	03.1	046.4	03
	29	33.5	22.8	93	83	07.3	02.5	429.1	06
	30	30.7	22.7	90	70	06.3	09.4	119.2	03
August	31	31.5	23.6	92	82	05.3	03.9	140.0	05
	32	31.9	22.7	93	85	06.7	01.5	118.5	06
	33	33.3	22.7	92	78	06.4	04.0	057.6	03
	34	32.9	22.9	93	70	03.2	06.3	014.6	03
September	35	33.5	22.8	96	71	04.5	05.8	150.6	07
	36	33.0	22.6	94	80	05.3	01.2	221.6	04
	37	31.9	22.4	93	73	05.1	03.9	092.2	03
	38	30.4	21.9	93	67	05.7	05.1	041.0	04
	39	31.3	20.8	86	56	05.1	06.9	000.0	00
October	40	32.2	18.6	90	47	03.1	09.0	005.2	01
	41	32.4	19.1	92	43	02.3	08.3	000.0	00
	42	32.6	15.8	89	31	02.5	09.3	000.0	00
	43	31.8	13.9	87	30	02.5	08.9	000.0	00
November	44	31.0	11.0	86	24	02.4	09.0	000.0	00
	45	31.8	12.1	89	29	02.5	08.3	000.0	00
	46	30.9	12.4	89	28	02.4	08.0	000.0	00

3.2 Experimental material

The experimental material for this study comprised of 20 genotypes with four checks HOK-152(C), Arka Anamika, Pusa sawani and SOH 152-RC(C) collected from different research institutes. Details of the genotypes and Commercial checks are presented in Table 3.2.

Table 3.2 Details of genotype and checks used in the study

S. No.	Name of genotypes	Source
1	Okra-hy-4	IIVR, Varanasi
2	Okra-hy-5	IIVR, Varanasi
3	Okra-hy-6	IIVR, Varanasi
4	Okra-hy-7	IIVR, Varanasi
5	Okra-hy-8	IIVR, Varanasi
6	Okra-hy-10	IIVR, Varanasi
7	Bhindi No-10	IIVR, Varanasi
8	Bhindi MHOK-12	IIVR, Varanasi
9	10/Okra hy-1	IIVR, Varanasi
10	10/Okra hy-2	IIVR, Varanasi
11	10/Okra hy-3	IIVR, Varanasi
12	10/Okra hy-4	IIVR, Varanasi
13	10/Okra hy-5	IIVR, Varanasi
14	10/Okra hy-6	IIVR, Varanasi
15	10/Okra hy-8	IIVR, Varanasi
16	10/Okra Hy-9	IIVR, Varanasi
17	HOK-152(C)	IIVR, Varanasi
18	Arka Anamika	IIHR, Bangalore
19	Pusa sawani	IARI, New Delhi
20	SOH 152-RC	IIVR, Varanasi

3.3 Experimental details

3.3.1 Design of experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) with 20 treatment (16genotypes + 4 checks) and three replications. The experimental details are as follows:-

Crop	:	Okra
Season	:	Kharif
Date of sowing	:	11/ 07/ 2011
Design	:	RCBD
Replications	:	3
Number of Genotypes	:	20
Plot size	:	3.0x2.7 sq.m
Total number of plots	:	60
Row to row distance	:	60 cm
Plant to Plant distance	:	30 cm
Number of rows in each plot	:	5
Number of plants per row	:	9
Total number of plants per plot	:	45
Distance between two plots	:	50 cm
Distance between replications	:	1.0 m
Fertilizer dose (N: P: K)	:	120:60:60 kg/ha
Number of plants for observation per plot	:	5

3.3.2 Field preparation and sowing

In order to get good tilth of the soil for sowing, one cross cultivation was done by tractor drawn cultivator followed by two harrowing and one planking before sowing of seed.

In the beginning of experiment, 2-3 seeds were dibbled. After two weeks of sowing, thinning was carried out to maintain single plant per hill. All the recommended package of practices was followed to raise healthy crop.

3.3.3 Irrigation

The irrigation was given to be as and when required.

3.3.4 Intercultural operations

The experimental plots were kept weed free through hand weeding. The crop was sprayed with chloropyriphose and trizophos alternate to keep the crop free from pest during crop growth period.

3.3.5 Fertilizer application

A basal dose of 120 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha along with 20 tonnes FYM/ha was applied. One third nitrogen and entire quantity of P and K was applied prior to sowing. Remaining dose of nitrogen was applied in two splits at 30 and 60 days after sowing.

3.3.6 Sampling

Sampling was done at 30 days interval upto harvest for growth analysis. Five plants were randomly selected from each treatment and replication for the study.

3.4 Observations

Five representative plants in each plot were selected randomly and tagged for recording data for various plant characters. The data recorded on various parameters were subdivided into three categories during the period of experiment.

(A) Morphological character

3.4.1 Plant height (cm)

Height of plant was recorded from the base just above the soil surface to the growing point of the plant. The height was recorded at (i) 30days after sowing (ii) 60 days after sowing and (iii) 90 days after sowing.

3.4.2 Number of branches per plant

Number of branches per plant was recorded at 30, 60 and 90 days after sowing.

3.4.3 Number of leaves per plant

The number of leaves of each selected plants was counted and average was worked out.

3.4.4 Number of nodes to first flowering

Numbers of nodes were counted at the time of first flowering.

3.4.5 Flowering nodes on main stem

The number of flowering nodes of each selected plant was counted and average was worked out for each genotype.

3.4.6 Length of internode (cm)

The internode length of the five randomly selected plants was recorded. The length measured between two nodes from different places such as base, middle and top with the help of scale and average was worked out for each genotype.

3.4.7 Days taken to 50% flowering

Average number of days required to 50% flowering in each genotype was recorded separately.

3.4.8 Days taken to first picking

Number of days required from the date of sowing to first picking of fruits was recorded.

3.4.9 Fruiting span (days)

Fruiting span is the duration between first and last picking was recorded to known the fruiting span of each genotype.

(B) Fruit characters

3.4.10 Length of fruit (cm)

The length of fruit was measured from randomly selected five fruits from every genotype with the help of scale and then average was recorded.

3.4.11 Diameter of fruit (cm)

The diameter of the randomly selected fruits was recorded with different position such as at base, at middle and at top with the help of thread and scale and average was worked out.

3.4.12 Weight of fruit (g)

Weight of five fruits was recorded separately with the help of weighing balance and average was worked out for each genotype.

3.4.13 Fruit colour

The colour of fruits was recorded at marketable stage in following categories.

- Dark green
- Green
- Light green

3.4.14 Fruit surface

The surface of fruits viz. smooth or hairy was recorded at marketable stage.

3.4.15 Number of seeds per fruit

The number of seeds in five randomly selected fruits from observational plants counted and average seeds per fruit were calculated.

3.4.16 Number of fruits per plant

The number of fruits harvested from five randomly selected plants in each genotype was collected during each picking, counted and average fruits per plant were calculated.

3.3.17 Yield per plant (g)

Picking of fresh marketable fruits was done from the observational plants separately throughout the harvesting period at an interval of 3 days. It was total and then average yield per plant was worked out for each genotype.

3.5 Statistical Methodology

The data obtained in respect of all the characters has been subjected to the following statistical analyses:

3.5.1 Mean

It was calculated by using following formula.

$$\text{Mean} = \frac{\Sigma X}{N}$$

where;

ΣX = Sum of all the observations.

N = Number of observations.

3.5.2 Analysis of variance

The data based on the mean of individual plants selected for observation were statistically analysed to find out overall total variability present in the material under study for each character and for all the populations. The first and foremost step is to carry out analysis of variance to test the significance of difference among the populations. The skeleton of analysis of variance used was as follows:

Table 3.3 ANOVA for Randomized Complete Block Design

Source of variation	d. f.	Sum of square	Mean sum of square	F value
Replication	r-1	RSS	RMS	RMS/EMS
Genotypes	g-1	GSS	GMS	GMS/EMS
Error	(r-1)(g-1)	ESS	EMS	-
Total	rg-1	TSS	-	-

Where,

r = Number of replications

g = Number of genotypes

d.f. = Degrees of freedom

RSS = Replication Sum of Square

GSS= Genotype Sum of Square

ESS = Error Sum of Square

TSS = Total Sum of Square

RMS = Replication Mean Sum of Square

GMS = Genotype Mean Sum of Square

EMS = Error Mean Sum of Square

A significant value of F test indicates that the test differ significantly among themselves which requires computing C.D.

$$\text{C. V.} = \frac{\sqrt{EMS}}{GM} X100$$

$$SEm\pm = \sqrt{\frac{EMS}{r}}$$

$$S\,E_{diff} = \sqrt{\frac{2EMS}{r}}$$

CD at 5% prob. level = SE diff x $t_{5\%}$ (table value)

where,

c.v. = Coefficient of variation

SEm± = Standard error of means

S E diff = Standard error of difference

GM =Grand mean

C.D. =Critical difference

t 5% = Table value at 5% probability level.

The component of variance was calculated as follows:-

S. No.	Source	M.S.S.	Expected M.S.S.
1	Replication	-	-
2	Treatment	M i	σ^2 e i + r. σ^2 g i
3	Error	E i	σ^2 e i

$$\sigma^2 g\,i = \frac{Mi - Ei}{r}$$

$$\sigma^2 e\,i = Ei$$

$$\sigma^2 p\,i = \sigma^2 g\,i + \sigma^2 e\,i$$

where,

σ^2 g i =Genotypic variance for i^{th} character.

σ^2 e i = Environment variance for i^{th} character.

σ^2 p i = Phenotypic variance for i^{th} character.

Phenotypic and genotypic coefficient of variance (expressed in %) were calculated by using the formula given by Burton (1952).

Genotypic coefficient of variation (GCV) calculated was as below:

$$GCV = \frac{\sqrt{\pm\, ^2g^i}}{\overline{Xi}} \times 100$$

Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sqrt{\pm\, ^2p^i}}{\overline{Xi}} \times 100$$

Xi = General mean of the i^{th} character under consideration

σ^2 g $_i$ and σ^2 p $_i$ = Genotypic and phenotypic standard deviation of the i^{th} character, respectively

Heritability and genetic advance

Heritability (broad sense) which is ratio of genotypic variance to the total phenotypic variance is symbolized as h^2 (b s) and expressed in percentage. Estimation of heritability was done as per the formula given by Hanson *et al*. (1956).

$$h^2 \text{ (b.s.)} = \frac{\sigma^2 \text{ g i}}{\sigma^2 \text{ p i}} \text{X100}$$

$$\text{or} = \frac{\text{Genotypic variance of the i character}}{\text{Phenotypic variance of the i character}}$$

Expected genetic advance was calculated by using the method suggested by Johnson *et al.* (1955) at 5% selection intensity.

$$\text{Genetic advance (GA)} = K.\ P_i.\ h^2_i$$

Genetic advance as percentage of mean was calculated as follows:

$$\frac{\text{Genetic advance}}{\bar{x}i}$$

where,

K= Selection intensity at 5% selection level i.e. 2.06

P_i=Phenotypic standard deviation of the i^{th} character

h^2_i= Broad sense heritability (fraction) of the i^{th} character

X_i= General mean of the i^{th} character under consideration

Correlation coefficients

Correlation coefficients were calculated in all possible combinations taking all the characters into consideration at genotypic, phenotypic and environmental levels by using the formula as proposed by Miller *et al.* (1958).

$$r = \frac{\Sigma xy - \frac{\Sigma x.\Sigma y}{n}}{\sqrt{\left(\Sigma x^2 - \frac{(\Sigma x)^2}{n}\right)\left(\Sigma y^2 - \frac{(\Sigma y)^2}{n}\right)}}$$

Where,

r = Correlation Coefficient

n = Number of treatments

x and y= Character under study

Genotypic, phenotypic and environmental correlations were computed by substituting corresponding variance and covariance in the above formula, e. g.

$$r_{G(x_i x_j)} = \frac{\Sigma xiyj - \frac{\Sigma xi.\Sigma yj}{n}}{\sqrt{\left(\Sigma xi^2 - \frac{(\Sigma xi)^2}{n}\right)\left(\Sigma yj^2 - \frac{(\Sigma yj)^2}{n}\right)}}$$

$$r_{P(x_i x_j)} = \frac{\Sigma xiyj - \frac{\Sigma xi.\Sigma yj}{n}}{\sqrt{\left(\Sigma xi^2 - \frac{(\Sigma xi)^2}{n}\right)\left(\Sigma yj^2 - \frac{(\Sigma yj)^2}{n}\right)}}$$

$$r_{E(x_i x_j)} = \frac{\Sigma xiyj - \frac{\Sigma xi.\Sigma yj}{n}}{\sqrt{\left(\Sigma xi^2 - \frac{(\Sigma xi)^2}{n}\right)\left(\Sigma yj^2 - \frac{(\Sigma yj)^2}{n}\right)}}$$

Testing of correlations

The phenotypic correlations are tested for their significance by following formula based on “t” test:

$$Tc = \frac{r}{\sqrt{1-r^2}} . \sqrt{n-2} \sim t\ (n\text{-}2)\ d.f.$$

where,

N=Number of treatments.

R=Phenotypic correlations coefficient.

The calculated value of “t” is compared with table of “t” at (n-2) d.f. if the calculated value is equal to or greater than table value, it is significant at given probability level. If $t_c < t_T$, it is to be non significant.

Path coefficient analysis

Path coefficient analysis was worked out to show the cause and effect relationship between yield and various yield components, and to partition the total correlation coefficient into direct and indirect effects.

This procedure was developed by Wright (1921) and as per concept used by Li (1956) and followed by Dewey and Lu (1959).

Path coefficients are the standardized partial regression coefficients and as such measure the direct influence of one variable upon another variable and permits partition of correlation coefficient into components of direct and indirect effects. The sum of the direct and all possible indirect effects via all other traits must be equal to correlation coefficient of dependent traits with independent characters under consideration.

Path coefficients were obtained by setting simultaneous equation which expresses basic relationship between correlation and path coefficient analysis:

$$r_{1,y} = P_{1,y} + r_{1,2} P_{2,y} + r_{1,2} P_{1yt} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + r_{1,10} P_{10,y}$$
$$r_{2,y} = P_{2,y} + r_{2,1} P_{1,y} + r_{2,2} P_{3yt} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + r_{2,10} P_{10,y}$$
.
.
$$r_{10,y} = P_{10,y} + r_{10,y} P_{1,y} + r_{10,2} P_{3yt} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + r_{10,9} P_{9,y}$$

Where,

1, 2, …. 10 are the component characters and y is dependent upon which direct and indirect effects are studied.

Unexplained variation of the residual effects was obtained from the following equation:

R= Residual effect.

Di= Direct effect of the i^{th} character.

Rij= Correlation coefficient between the i^{th} character and j^{th} dependent character.

Direct and indirect effect of yield per plant was calculated at both genotypic and phenotypic levels.

RESULTS

The present investigation entitled “Evaluation of genetic variability, correlation studies and path analysis of okra [*Abelmoschus esculentus* (L.) Monch] under Jabalpur condition” was carried out to determine the following objectives:

1. To estimate the genetic variability and heritability of genotypes.
2. To analyse the correlation of yield with it’s contributing parameters.
3. To quantify path coefficient analysis.
4. To identify better genotypes in relation to yield under Jabalpur condition.

The results obtained from the present investigations are presented under the following heads:-

4.1 Analysis of variances

4.2 Genetic variability

4.2.1 Mean performance

4.2.2 Coefficient of variation

4.2.3 Heritability and genetic advance

4.3 Correlation coefficient analysis

4.4 Path coefficient analysis

4.1 Analysis of variances

The analysis of variance showed significant differences due to treatments for all the growth and yield attributing characters under study. The estimated values are depicted in Table 4.1.

Table 4.1 Analysis of variance for nineteen characters in twenty genotypes of okra [*Abelmoschus esculentus* (L.) Monch.]

Source of variation	d.f.	Plant height (cm)			Number of branches per plant			Number of leaves per plant
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	
Replication	2	6.722	16.392	30.368	2.428	0.974	3.024	4.074
Treatment	19	585.48**	761.652**	414.038**	0.062*	0.797**	2.259**	16.081*
Error	38	5.112	8.374	6.629	0.032	0.317	0.800	7.425

Cont..

Source of variation	d.f.	Number of nodes to first flower	Number of flowering nodes on main stem	Length of internodes (cm)	Days taken to 50% flowering (days)	Days taken to first picking (days)	Fruiting span (days)
Replication	2	2.812	37.266	9.957	19.216	58.400	55.266
Treatment	19	0.117*	4.291**	8.239**	2.908**	7.424**	7.224**
Error	38	0.067	0.501	1.956	0.374	1.277	1.371

Cont..

Source of variation	d.f.	Length of fruit (cm)	Diameter of fruit (cm)	Weight of fruit (g)	Number of seeds per fruit	Number of fruits per plant	Yield per plant (g)
Replication	2	24.510	0.188	0.516	23.478	1.022	33.842
Treatment	19	1.522**	0.012**	7.043*	115.853**	8.698**	1143.558**
Error	38	0.481	0.002	2.947	7.562	3.525	9.593

* Significant at 5% level of significance ** Significant at 1% level of significance

4.2 Genetic variability

4.2.1 Mean performance

The mean performances of the genotypes for all the 19 characters are depicted in Table 4.2

Plant height at 30, 60 and 90 DAS (cm)

The plant height at 30 DAS varied from 19.13 to 62.46 cm with a mean performance of 39.86 cm. Pusa sawani recorded maximum plant height of 62.46 cm. while, genotype 10/okra-hy-9 had the lowest height (19.13cm).

Plant height at 60 DAS ranged from 91.60 to 148.67 cm with mean of 117.38cm. The genotype SOH-152 recorded the maximum plant height of 148.67cm. While, genotype10/okra-hy-9 had the lowest height of 91.60 cm.

In respect of plant height at 90 days after sowing, ranged from 144.33 to 187.00 cm with a mean performance of 159.725 cm. Highest plant height (187.00 cm) was noted in the genotype Okra-hy-5. However, lowest plant height (144.33cm) was recorded in the genotype Hok-152.

Branches per plant at 30, 60 and 90 DAS

Number of branches per plant at 30 DAS ranged from 0.40 to 0.87 with mean of 0.57. SOH-152 showed highest number of branches per plant (0.87) While, 10/okra-hy-2 produced the lowest number of branches (0.40).

Number of branches per plant at 60 DAS, with mean of 1.56 ranged from 0.87 to 2.60. Maximum branches per plant (2.60) were observed in genotype SOH-152. Minimum branches per plant were found in the genotype 10/okra-hy-4 (0.87).

Table- 4.2(a) Mean performance of nineteen characters in twenty genotypes of okra [*Abelmoschus esculentus* (L.) Monch]

Characters	Plant height (cm)			No. of branches per plant			No. of leaves per plant	No. of nodes to first flower	Flowering nodes on main stem	Length of internodes (cm)	Days to 50% flowering (days)	Days to first picking (days)	Fruiting span (days)	Length of fruit (cm)	Diameter of fruit (cm)	Weight of fruit (g)	No. of seeds per fruit	No. of fruits per plant	Yield per plant (g)
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS													
Okra-hy-4	59.67	116.53	159.26	0.67	1.67	3.13	31.80	5.00	17.87	13.36	45.67	50.33	47.67	16.14	1.57	14.13	57.40	23.40	252.67
Okra-hy-5	52.40	147.20	187.00	0.73	2.20	4.13	34.40	5.20	17.47	13.30	47.00	51.67	46.33	16.52	1.66	14.30	64.27	26.40	261.00
Okra-hy-6	51.40	136.80	171.93	0.60	1.87	3.40	34.80	5.00	17.60	14.67	45.67	50.3	47.67	16.79	1.70	13.40	67.27	22.80	290.33
Okra-hy-7	57.06	126.53	157.73	0.40	1.87	3.60	31.53	4.60	19.33	16.43	45.33	51.67	46.33	16.57	1.68	15.69	55.00	22.26	268.00
Okra-hy-8	43.40	121.86	156.47	0.53	1.53	3.00	30.93	5.13	18.53	15.23	45.33	50.33	47.67	17.77	1.64	14.67	71.40	24.20	240.00
Okra-hy-10	51.53	123.80	160.20	0.73	2.47	4.13	34.00	4.73	19.40	14.45	45.67	53.67	45.00	17.28	1.74	16.24	59.67	22.46	303.00
Bhindi No.-10	52.33	128.67	168.27	0.40	1.46	3.27	34.67	5.13	19.46	15.46	45.33	51.67	46.33	16.57	1.66	15.07	54.86	23.00	266.00
Bhindi MHOK-12	52.20	111.73	153.67	0.67	1.73	3.87	31.06	5.20	18.46	17.30	45.00	52.33	45.67	15.97	1.62	13.11	59.73	21.20	238.00
10/Okra-hy-1	27.00	104.80	149.06	0.47	0.93	1.87	28.47	4.93	17.90	11.67	45.67	51.67	46.33	15.58	1.56	14.16	70.93	19.40	282.67
10/Okra-hy-2	29.53	100.73	15.47	0.40	0.93	1.86	29.33	4.80	20.73	12.75	45.67	51.67	46.33	16.06	1.65	17.88	66.46	23.67	248.00
10/Okra-hy-3	25.26	108.06	147.20	0.60	1.26	2.00	31.53	5.00	17.46	13.02	46.67	53.67	44.33	15.80	1.70	16.45	66.20	22.00	247.00
10/Okra-hy-4	24.67	98.93	155.73	0.46	0.87	1.93	31.60	5.13	19.73	12.41	45.67	53.00	45.00	17.49	1.62	16.75	62.53	23.13	263.67
10/Okra-hy-5	34.67	117.60	158.26	0.53	1.00	2.13	30.067	4.66	19.20	12.50	48.00	53.67	44.33	16.67	1.65	15.99	58.33	24.26	243.53
10/Okra-hy-6	27.60	112.13	157.33	0.40	1.00	2.20	31.60	5.06	19.00	14.30	48.00	54.33	43.67	15.72	1.56	16.58	74.26	22.20	272.00
10/Okra-hy-8	22.60	104.93	152.33	0.46	1.40	2.20	33.00	5.06	18.40	14.77	46.33	54.33	43.67	15.58	1.54	14.64	72.20	23.40	238.67
10/Okra-hy-9	19.13	91.60	144.40	0.40	1.06	2.20	31.26	5.20	17.93	14.59	47.67	55.00	43.00	16.55	1.67	16.89	58.60	22.067	239.33
HOK-152	27.40	97.26	144.33	0.73	1.40	2.20	28.93	5.00	17.53	12.39	46.67	55.00	43.00	17.64	1.81	12.09	66.26	21.067	232.67
Arka Anamika	56.40	120.33	160.26	0.53	1.73	3.06	32.80	4.80	21.86	15.56	45.33	51.67	46.33	15.70	1.67	15.34	63.20	26.60	254.33
Pusa Sawani	62.46	129.13	170.20	0.73	2.00	3.73	32.73	4.73	18.53	16.89	45.33	51.67	46.33	15.45	1.68	17.42	57.46	22.33	281.00
SOH 152-RC	40.46	148.86	185.33	0.87	2.60	4.40	38.27	5.26	17.13	16.42	44.67	50.33	47.67	16.53	1.65	16.81	72.93	24.73	269.00
SEm±	1.27	1.62	1.45	0.10	0.31	0.503	1.53	0.14	0.39	0.78	0.34	0.63	0.65	0.39	0.02	0.96	1.54	1.05	1.74
CD at 5%	3.73	4.78	4.25	0.29	0.93	1.47	4.50	0.39	1.170	2.31	1.011	1.86	1.93	1.14	0.08	2.83	4.54	3.10	5.11

Number of branches per plant at 90 DAS varied from 1.84 to 4.40 with mean of 2.92. The genotype SOH-152 recorded maximum branches per plant (4.40), while minimum branches per plant (1.86) was noted in genotype 10/okra-hy-2.

Number of leaves per plant

Number of leaves per plant varied from 28.47 to 38.26 with an average of 32.14. The maximum leaves per plant (38.26) were recorded in SOH-152. However, minimum number of leaves per plant was observed in genotype 10/okra-hy-1 (28.47).

Number of nodes to first flower

Number of nodes to first flower ranged from 4.60 to 5.26 with an overall average of 4.68. The highest number of nodes to first flower (5.26) was found in the genotype SOH-152.While, the lowest number of nodes to first flower (4.60) was exhibited in genotype okra-hy-7.

Number of flowering nodes on main stem

Number of flowering nodes per plant varied from 17.13 to 21.86 with an average of 18.68. Highest number of flowering nodes on main stem was observed in the genotype Arka Anamika (21.86) whereas lowest was depicted in the genotype SOH-152 (17.13).

Length of internodes (cm)

The internodal length varied from 11.67 to 17.30 cm with a mean of 14.37 cm. 10/okra-hy-1 had lowest internodal length of 11.67 cm, while Bhindi MHOK-12 exhibited maximum internodal length of 17.30 cm.

Days to 50 per cent flowering (days)

Days to 50 per cent flowering varied from 44.67 to 48.00 days with an average of 46.03 days. Check variety SOH-152 observed minimum days for 50 per cent flowering (44.67 days). However, maximum days to 50 percent flowering were observed in the genotype 10/okra-hy-5 (48.00 days).

Days to first picking (days)

Days to first picking ranged from 50.33 to 55.00 days with an average of 52.40 days. Early first picking was noted in genotype SOH-152 (52.40 days) whereas, the maximum days to first picking (55.00days) was observed in two genotypes HOK-152 and 10/okra-hy-9.

Fruiting span (days)

The range for fruiting span varied from 43.00 to 47.67 days with an average of 45.63 days. Maximum fruiting span was observed in genotype SOH-152 (47.67 days) while, the minimum fruiting span was recorded in genotype HOK-152 (43.00 days).

Length of fruit (cm)

Fruit length varied from 15.45 cm to 17.78 cm with an overall mean performance of 16.42 cm. Genotype Okra-hy-8 produced longest fruit (17.78 cm), while, smallest fruit was recorded in Pusa sawani (15.45 cm).

Diameter of fruit (cm)

The diameter of fruit varied from1.54 to1.74 cm with an average of 1.65 cm. Maximum 1.74 cm diameter of fruit was recorded in

genotype Okra-hy-10. However, minimum diameter of fruit was observed in genotype 10/okra-hy-8 (1.548).

Weight of fruit (g)

Average weight of fruit was recorded to be 15.39 g, with the range of 12.09 to 17.88 g. The maximum weight of fruit was recorded in 10/okra-hy-2 (17.88g) and minimum weight of fruit was exhibited by HOK-152 (12.09g).

Number of seeds per fruit

The number of seed per fruit varied from 54.86 to 74.26 with an average of 63.95. 10/okra-hy-6 had highest number of seeds per fruit (74.26) and Bhindi No-10 produced lowest (54.86) number of seed per fruit.

Number of fruits per plant

Number of fruits per plant ranged from 19.40 to 26.60 with the mean of 23.03. Highest number of fruits per plant was observed in Arka Anamika (26.60) whereas, lowest was depicted in 10/okra-hy-1 (19.40).

Yield per plant (g)

Yield per plant varied from 232.67 to 303.00 g with the average of 259g. Highest yielding genotype was Okra-hy-10 (303.00g) while HOK-152 gave the lowest (232.67g) yield per plant.

Fruit colour and Fruit surface

The fruit colours were observed as dark green, green and light green and fruit surface was recorded as smooth and hairy. The result obtained by visual observation is depicted in Table 4.2(b).

Table 4.2(b) Fruit colour and fruit surface

S. No.	Varieties	Colour	Surface
1	Okra-hy-4	Dark green	Smooth
2	Okra-hy-5	Green	Hairy
3	Okra-hy-6	Green	Smooth
4	Okra-hy-7	Light green	Hairy
5	Okra-hy-8	Green	Smooth
6	Okra-hy-10	Light green	Hairy
7	Bhindi No-10	Green	Hairy
8	Bhindi MHOK-12	Green	Hairy
9	10/Okra hy-1	Dark green	Smooth
10	10/Okra hy-2	Green	Smooth
11	10/Okra hy-3	Dark green	Smooth
12	10/Okra hy-4	Dark green	Smooth
13	10/Okra hy-5	Green	Smooth
14	10/Okra hy-6	Dark green	Hairy
15	10/Okra hy-8	Light green	Smooth
16	10/Okra Hy-9	Green	Hairy
17	HOK-152(C)	Light green	Hairy
18	Arka Anamika	Green	Smooth
19	Pusa sawani	Green	Smooth
20	SOH 152-RC	Light green	Smooth

4.2.2 Coefficient of variation

Estimation of component of genetic parameters of variation for fruit yield and its attributes exhibited a wide range of variation for the characters studied (Table 4.3). Results indicated that the values of phenotypic coefficient of variation were of higher magnitude than that of genotypic coefficient of variations for all the characters showing that environment had an important role in influencing the expression of the characters.

Table 4.3 Estimates of genetic parameters for variations of nineteen characters in okra

Characters	General mean	Range		Coefficient of variation		Heritability (b.s. %)	Genetic advance	GA as % of mean
		Min.	Max.	Phenotypic (PCV)	Genotypic (GCV)			
Plant height at 30 DAS (cm)	39.860	19.13	62.46	35.35	34.89	97.43	28.28	70.95
Plant height at 60 DAS (cm)	117.376	91.60	148.67	13.72	13.50	96.77	32.11	27.35
Plant height at 90 DAS (cm)	159.725	144.33	187.00	7.47	7.29	95.35	23.44	14.67
No. of branches per plant at 30 DAS	0.57	0.40	0.87	36.48	17.52	23.07	0.09	17.33
No. of branches per plant at 60 DAS	1.56	0.86	2.60	44.58	25.78	33.40	0.47	30.71
No. of branches per plant at 90 DAS	2.92	1.87	4.40	38.89	23.913	37.81	0.88	30.29
No. of leaves per plant	32.14	28.47	38.26	9.99	5.285	27.98	1.85	5.75
No. of nodes to first flower	4.68	4.60	5.26	5.82	2.598	19.92	0.11	2.38
Flowering nodes on main stem	18.68	17.13	21.86	7.11	6.016	71.57	1.95	10.48
Length of internodes (cm)	14.37	11.67	17.30	14.001	10.06	51.70	2.14	14.91
Days to 50% flowering (days)	46.03	44.67	48.00	2.39	1.99	69.28	1.57	3.42
Days to first picking (days)	52.40	50.33	55.00	3.48	2.73	61.60	2.31	4.41
Fruiting span(days)	45.63	43.00	47.67	3.99	3.06	58.71	2.204	4.83
Length of fruits(cm)	16.42	15.45	17.78	5.54	3.58	41.84	0.78	4.77
Diameter of fruits(cm)	1.65	1.548	1.74	4.56	3.50	58.98	0.091	5.54
Weight of fruits(g)	15.39	12.09	17.88	13.48	7.58	31.66	1.35	8.79
No. of seeds per fruit	63.95	54.86	74.26	10.33	3.39	82.68	11.25	47.59
No. of fruit per plant	23.03	19.40	26.60	9.94	5.70	32.85	1.55	6.73
Yield per plant	259.54	232.67	303.00	7.58	7.49	97.52	39.55	15.23

The highest phenotypic coefficient of variation was observed for number of branches per plant at 60 DAS (44.58) followed by number of branches per plant at 90 DAS (38.89) and number of branches per plant at 30 DAS (35.35). Lowest phenotypic coefficient of variation was observed for days to 50% flowering (2.39) followed by days to first picking (3.48), fruiting span (3.99), length of fruits (5.54) and number of nodes to first flower (5.82).

Moderate phenotypic coefficient of variation was recorded for length of internode (14.001) followed by plant height at 60 DAS (13.72) and weight of fruit (13.48).

The highest genotypic coefficient of variation was observed for plant height at 30 DAS (34.89), number of branches per plant at 60 DAS (25.78) and number of branches per plant at 90 DAS (23.913). Lowest genotypic coefficient of variation was observed for days to 50% flowering (1.99), number of nodes to first flower (2.59) and days to first picking (2.73).

4.2.3 Heritability and genetic advance

Heritability

Heritability (broad sense) was computed for each of the characters by the variance components estimating their relative magnitudes of genotypic and phenotypic variability contributed through environmental factors. It was partitioned as very high (> 90%), high (70-90%) medium (50-70%) and low (<50%). Heritability was ranged from 19.92% for number of nodes to first flower to 97.52% for yield per plant (Table 4.3).

Result indicated that heritability (broad sense) was found to be very high for yield per plant (97.52%), plant height at 30 DAS (97.43%), plant height at 60 DAS (96.77%) and plant height at 90 DAS (95.35%). However, it was recorded to be high for number of seeds per fruit

(82.68%) and number of flowering nodes on main stem (71.57%). Days to 50% flowering (69.28%), days to first picking (61.60%), diameter of fruit (58.98%), fruiting spans (58.71%) and length of internodes (51.70%) exhibited moderate heritability. Low estimates of heritability was recorded for length of fruit (41.84%), number of branches per plant at 90 DAS (37.81), number of branches per plant at 60 DAS (33.40), number of fruits per plant (32.85), weight of fruit (31.66), number of leaves per plant (27.98%), number of branches per plant at 30 DAS (23.07) and number of nodes to first flower (19.92).

Genetic Advance

Based on the estimates of heritability (broad sense) expected genetic advance was computed on the hypothetical selection at 5 per cent best individual (K=2.06). Due to masking influence of environment upon characters, concerned values of genetic advance exhibited high fluctuation. Genetic advance as percentage of mean was partitioned as high (above 20%), medium (10-20%) and low (below 10%).

The highest estimate of genetic advance as percentage of mean was recorded in plant height at 30 DAS (70.95%) followed by number of seeds per fruit (47.59%), branches per plant at 60 DAS (30.71%) number of branches per plant at 90 DAS (30.29%) and plant height at 60 DAS (27.35%). While, moderate value was observed for number of branches per plant at 30 DAS (17.33%) followed by yield per plant (15.23%), length of internode (14.91%), plant height at 90 DAS (14.67%) and number of flowering nodes on main stem (10.48%). However, the estimates were low for weight of fruit (8.79%), number of fruits per plant (6.73), number of leaves per plant (5.57%), diameter of fruit (5.54%), fruiting span (4.83%), length of fruit (4.77%), days to first picking (4.41%), days to 50% flowering (3.42%) and number of nodes to first flower (2.38%).

4.3 Correlation coefficient analysis

Correlation coefficient were worked out at phenotypic and genotypic levels for all possible combination of 19 characters, results indicated that phenotypic coefficients, in general were higher magnitude than the corresponding genotypic ones.

Plant height at 30 DAS (cm)

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

Plant height at 60 DAS (cm)

Plant height at 60 DAS showed significant and positive association with plant height at 90 DAS (0.89), plant height at 30 DAS (0.66), number of branches per plant at 90 DAS (0.64), number of branches per plant at 60 DAS (0.60), fruiting span (0.57), number of leaves per plant (0.542) ,days to first picking (0.54), yield per plant (0.47), number of fruits per plant (0.39) and number of branches per plant at 30 DAS (0.36). However, significant and negative correlation was observed with days to 50% flowering (-0.30).

Plant height at 90 DAS (cm)

A significant and positive correlation was shown by this trait with plant height at 60 DAS (0.89), plant height at 30 DAS (0.58), number of leaves per plant (0.57), number of branches per plant at 90 DAS (0.55),

Table 4.4 Phenotypic and genotypic correlation coefficient of yield and its contributing traits in okra

Characters		Plant height at (cm)		No. of branches per plant at			No. of leaves per plant	No. of nodes to first flower	Flowering nodes on main stem	Length of internode (cm)	Days to 50% flowering (days)	Days to first picking (days)	Fruiting span (days)	Length of fruit (cm)	Diameter of fruit (cm)	Weight of fruit (g)	No. of seeds per fruit	No. of fruit per plant	Yield per plant (g)
		60 DAS	90 DAS	30 DAS	60 DAS	90 DAS													
Plant height at 30 DAS (cm)	P	0.66**	0.58**	0.34**	0.47**	0.57**	0.31*	-0.10	0.11	0.39**	-0.44**	-0.53**	0.56**	-0.03	0.11	-0.12	-0.39**	0.26*	0.34**
	G	0.68	0.60**	0.70**	0.88**	0.97**	0.60**	-0.21	0.11	0.58**	-0.53**	-0.70**	0.73**	-0.08	0.150	-0.26*	-0.43**	0.47**	0.36**
Plant height at 60 DAS (cm)	P		0.89**	0.36**	0.60**	0.64**	0.54**	0.04	-0.15	0.36**	-0.30**	-0.54**	0.57**	0.02	0.10	0.02	-0.03	0.39**	0.47**
	G		0.93**	0.74**	1.02	1.02	0.93**	0.05	-0.201	0.53**	-0.37**	-0.71**	0.72**	0.03	0.10	-0.06	-0.03	0.64**	0.48**
Plant height at 90 DAS (cm)	P			0.34**	0.52**	0.55**	0.57**	0.118	-0.118	0.27*	-0.23	-0.50**	0.50**	0.015	0.04	0.66**	0.024	0.4**	0.43**
	G			0.70**	0.88**	0.92**	0.87**	0.24	-0.156	0.39**	-0.31	-0.67	0.68	-0.011	0.09	0.13	0.02	0.77**	0.45**
No. of branches per plant at 30 DAS	P				0.48**	0.38**	0.20	-0.02	-0.41**	0.15	-0.16	-0.05	0.209	0.13	0.24	-0.16	0.021	-0.01	0.10
	G				0.94**	0.82**	0.92**	0.54**	-0.60**	0.23	-0.42**	0.47	0.33	0.179	0.61	-0.37**	0.07	0.50**	0.24
No. of branches per plant at 60 DAS	P					0.89**	0.49**	-0.09	-0.10	0.25*	-0.34**	-0.28*	0.33**	0.01	0.22	-0.056	-0.05	0.28*	0.31*
	G					0.96**	0.87**	0.21	-0.35**	0.98**	-0.63**	-0.59	0.63	0.22	0.46	-0.18	-0.18	0.43**	0.53**
No. of branches per plant at 90 DAS	P						0.43**	-0.06	-0.07	0.31*	-0.37**	-0.35**	0.41**	-0.03	0.10	-0.09	-0.18	0.26*	0.31*
	G						0.64**	0.29*	-0.23	0.91**	-0.65**	-0.67	0.69	0.218	0.36	-0.14	-0.34**	0.41**	0.51**
No. of leaves per plant	P							0.23	-0.15	0.37**	-0.29*	-0.16	0.20	0.05	-0.02	0.09	0.02	0.44**	0.28*
	G							0.50**	-0.22	0.71**	-0.46**	-0.62	0.63	-0.02	0.14	0.24	0.04	0.57**	0.58**
No. of nodes to first flower	P								-0.35**	0.13	-0.09	-0.08	0.017	0.04	-0.27*	-0.20	0.27*	0.07	-0.18
	G								-0.72**	-0.05	0.02	0.05	0.02	0.31*	-0.21	-0.33	0.55**	0.01	-0.44**
Flowering nodes on main stem	P									0.06	-0.14	-0.014	-0.08	-0.09	-0.02	0.29*	-0.22	0.25*	0.013
	G									0.13	-0.16	0.005	0.09	-0.08	-0.08	0.43**	-0.26*	0.40**	0.03
Length of internode (cm)	P										-0.36**	-0.17	0.19	-0.17	-0.04	0.08	-0.16	0.18	0.09
	G										-0.59**	-0.40	0.4	-0.18	0.07	0.05	-0.25*	0.09	0.109
Days to 50% flowering (days)	P											0.52**	-0.54**	-0.04	0.13	0.04	0.07	0.02	-0.24*
	G											0.83	-0.85	-0.02	-0.06	0.14	0.10	-0.07	-0.29*
Days to first picking (days)	P												-0.80**	0.122	0.116	0.112	0.02	-0.29*	-0.26*
	G												-0.93	-0.08	0.21	0.03	-0.02	-0.37**	-0.33**
Fruiting span (days)	P													-0.04	-0.03	-0.06	-0.05	0.23	0.30*
	G													0.06	-0.23	-0.05	-0.03	0.44**	0.39**
Length of fruit (cm)	P														0.31*	-0.07	-0.03	-0.02	-0.04
	G														0.73**	-0.39**	-0.12	0.22	-0.05
Diameter of fruit (cm)	P															-0.09	-0.30*	0.02	0.02
	G															-0.14	-0.13	-0.08	0.06
Weight of fruit (g)	P																0.02	0.11	0.19
	G																-0.15	0.29*	0.26*
No. of seeds per fruit	P																	-0.1	-0.02
	G																	0.04	-0.04
No. of fruit per plant	P																		-0.09
	G																		-0.162

number of branches per plant at 60 DAS (0.52), fruiting span (0.50), yield per plant (0.43), number of fruits per plant (0.40), number of branches per plant at 30 DAS (0.34) and length of internode (0.27). Significant and negative correlation was observed with days to first picking (-0.50).

Number of branches per plant at 30 DAS

Number of branches per plant at 30 DAS had significant and positive correlation with number of branches per plant at 60 DAS (0.48), number of branches per plant at 90 DAS (0.388), plant height at 60 DAS (0.36), plant height at 30 DAS (0.349), plant height at 90 DAS (0.34) and diameter of fruit (0.24). Significant and negative correlation was exhibited with number of flowering nodes on main stem (-0.41).

Number of branches per plant at 60 DAS

Number of branches per plant at 60 DAS showed Significant and positive correlation with number of branches per plant at 90 DAS (0.89), plant height at 60 DAS (0.60), plant height at 90 DAS (0.52), number of leaves per plant (0.49), number of branches per plant at 30 DAS (0.48), plant height at 30 DAS (0.47), fruiting span (0.33), yield per plant (0.31), number of fruits per plant (0.28) and length of internode (0.25). Significant and negative correlation was recorded with days to 50% flowering (-0.34) and days to first picking (0.28).

Number of branches per plant at 90 DAS

Number of branches per plant at 90 DAS exhibited significant and positive correlation with number of branches per plant at 60 DAS (0.89), plant height at 60 DAS (0.64), plant height at 30 DAS (0.57), plant height at 90 DAS (0.55), number of leaves per plant, (0.43), fruiting span (0.41), number of branches per plant at 30 DAS (0.38), length of internode (0.31) and yield per plant (0.31) and number of fruits per plant

(0.26). However, it showed significant and negative correlation with days to 50% flowering (-0.37) and days taken to first picking (-0.35).

Number of leaves per plant

Number of leaves per plant expressed significant and positive association with number of branches per plant at 30 DAS (0.57), plant height at 60 DAS (0.54), number of branches per plant at 60 DAS (0.49), number of fruits per plant (0.44), number of branches per plant at 90 DAS (0.43), length of internode (0.37), plant height at 30 DAS (0.31) and yield per plant (0.28).it showed significant and negative association with days to 50% flowering (-0.29).

Number of nodes to first flower

Number of nodes to first flower revealed significant and positive correlation with number of seeds per fruit (0.27). However, significant and negative association was observed with number of flowering nodes on main stem (-0.35) and diameter of fruit (-0.27).

Number of flowering nodes on main stem

Number of flowering nodes on main stem exhibited significant and positive correlation with weight of fruit (0.29) and number of fruit per plant (0.25). However, significant and negative association was observed with number of branches per plant at 30 DAS (-0.41) and number of nodes to first flower (-0.35).

Length of internode (cm)

Length of internode expressed significant and positive correlation with plant height at 30 DAS (0.39), number of leaves per plant (0.37), plant height at 60 DAS (0.36), number of branches per plant at 90 DAS (0.31), plant height at 90 DAS (0.27), number of branches per plant at 60 DAS (0.25). It showed significant and negative correlation with days to 50% flowering (-0.36).

Days to 50% flowering (days)

Significant and positive association was observed by days to 50% flowering with days to first picking (0.52). However, it showed significant and negative association with fruiting span (-0.54), plant height at 30 DAS (-0.44), number of branches per plant at 90 DAS (-0.37), length of internode (-0.36), number of branches per plant at 60 DAS (-0.34)**,** plant height at 60 DAS (-0.30), number of leaves per plant (-0.29) and yield per plant (-0.24).

Days to first picking (days)

Days to first picking revealed significant and positive correlation with plant height at 60 DAS (0.54) and days to 50% flowering (0.52).This trait showed significant and negative correlation with fruiting span (-0.80), plant height at 30 DAS (-0.53), plant height at 90 DAS (-0.50), number of branches per plant at 90 DAS (-0.35)**,** number of fruits per plant (-0.29), number of branches per plant at 60 DAS (-0.28) and yield per plant (-0.26).

Fruiting span (days)

Significant and positive correlation was expressed by fruiting span with plant height at 60 DAS (0.57) plant height at 30 DAS (0.56), plant height at 90 DAS (0.50), number of branches per plant at 90 DAS (0.41), number of branches per plant at 60 DAS (0.33) and yield per plant (0.30). While, it's significant and negative correlation recorded with days to first picking (-0.80), and days to 50% flowering (-0.54)

Length of fruit (cm)

Length of fruit showed significant and positive correlation with diameter of fruit (0.31).

Diameter of fruit (cm)

Significant and positive correlation was revealed by diameter of fruit with length of fruit (0.31). However, it showed significant and negative correlation with number of seeds per fruit (-0.30) and number of nodes to first flower (-0.27).

Weight of fruit (g)

Weight of fruit showed significant and positive association with number of flowering nodes on main stem (0.29).

Number of seeds per fruit

Number of seeds per fruit expressed significant and positive correlation with number of nodes to first flower (0.27). While, significant and negative association was recorded with plant height at 30 DAS (-0.39) and diameter of fruit (-0.30).

Number of fruits per plant

Number of fruits per plant showed significant and positive association with number of leaves per plant (0.44), plant height at 90 DAS (0.40), plant height at 60 DAS (0.39), number of branches per plant at 60 DAS (0.28), number of branches per plant at 90 DAS and plant height at 30 DAS (0.26) and number of flowering nodes on main stem (0.25). However, it showed significant and negative correlation with days to first picking (-0.29).

Yield per plant (g)

Yield per plant exhibited significant and positive association with plant height at 60 DAS (0.47), plant height at 90 DAS (0.43), plant height at 30 DAS (0.34), number of branches per plant at 60 DAS(0.31), and number of branches per plant at 90 DAS (0.31), fruiting span (0.30) number of leaves per plant (0.28). However, it showed significant and negative correlation with days to first picking (-0.26) and days to 50% flowering (-0.24).

4.4 Path coefficient analysis

To measure the direct as well as indirect association of one variable (cause) through another on the end product (effect), path coefficient was calculated at genotypic and phenotypic levels for all the yield attributing traits. The observed correlation coefficients of yield with its components were partitioned into direct and indirect effects. In the present investigation, fruit yield per plant has been used as a dependable variable with other characters and discussed here. Since the values of genotypic path more reliable in predicting the correct ideas about the direct and indirect effects of the component traits, only this has been discussed here.

The results to path coefficient analysis showing direct indirect effects on fruit yield per plant (as dependable variable) is given as below (Table 4.5 a& b).

Direct effects

Plant height at 90 DAS had the highest positive direct effect (3.764) on fruit yield per plant followed by diameter of fruit (2.055), number of branches per plant at 90 DAS (1.017), number of seeds per fruit (0.705), days to 50% flowering (0.352), length of internode (0.285), number of flowering nodes on main stem (0.219) and fruiting span (0.184).

Number of branches per plant at 60 DAS exhibited negative direct effect on fruit yield per plant (-1.890) followed by plant height at 60 DAS (-1.3160), number of fruits per plant (-1.0956), length of fruit (-0.9813), number of branches per plant at 30 DAS (-0.6979), weight of fruit (-0.6933), days to first picking (-0.6132), number of nodes to first flower (-0.3683), number of leaves per plant (-0.2489) and plant height at 30 DAS (-0.099).

Table 4.5a Genotypic path coefficients showing direct and indirect effects of different characters on fruit yield per plant

Characters	Plant height (cm)			Number of branches per plant			Number of leaves per plant	Number of nodes to first flower	Number of flowering nodes on main stem	Length of internode (cm)	Days to 50% flowering (days)	Days to first picking (days)	Fruiting span (days)	Length of fruit (cm)	Diameter of fruit (cm)	Weight of fruit (g)	Number of seeds per fruit	Number of fruits per plant	Yield per plant (g)
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS													
Plant height at 30 DAS (cm)	**-0.099**	-0.068	-0.060	-0.070	-0.088	-0.097	-0.06	0.0216	-0.0113	-0.058	0.0533	0.0705	-0.073	0.0080	-0.015	0.0267	0.0432	-0.04	0.363
Plant height at 60 DAS (cm)	-0.900	**-1.316**	-1.233	-0.975	-1.347	-1.352	-1.41	-0.071	0.2651	-0.700	0.4876	0.9387	-0.956	-0.048	-0.135	0.0887	0.0448	-0.85	0.484
Plant height at 90 DAS (cm)	2.281	3.527	**3.764**	2.664	3.330	3.479	4.11	0.936	-0.5902	1.4829	-1.197	-2.517	2.584	-0.042	0.0032	0.5187	0.0106	2.903	0.456
Number of branches per plant at 30 DAS	-0.490	-0.577	-0.494	**-0.697**	-0.856	-0.738	-0.64	-0.367	0.4246	-0.1622	0.2958	0.3308	-0.234	-0.125	-0.431	0.2648	-0.055	-0.35	0.241
Number of branches per plant at 60 DAS	-1.672	-1.935	-1.673	-2.319	**-1.890**	-1.91	-2.20	-0.410	0.6778	-1.8716	1.2053	1.1238	-1.202	-0.419	-8765	0.3513	0.3459	-0.81	0.530
Number of branches per plant at 90 DAS	0.987	1.045	0.940	1.076	1.028	**1.017**	1.184	0.304	-0.2431	1.1302	-0.663	-0.688	0.7117	0.2222	0.3686	-0.143	0.3479	0.417	0.513
number of leaves per plant	-0.150	-0.268	-0.272	-0.229	-0.289	-0.289	**-0.24**	-0.126	0.0558	-0.1787	0.1166	0.1556	-0.159	0.0060	-0.035	-0.060	-0.010	-0.14	0.587
Number of nodes to first flower	0.079	-0.020	-0.091	-0.199	-0.080	-0.110	-0.18	**-0.368**	0.2674	0.0214	-0.007	-0.018	-0.007	-0.116	0.0808	0.1222	-0.205	-0.05	-0.44
Number of flowering nodes on main stem	0.024	-0.044	-0.034	-0.133	-0.078	-0.052	-0.04	-0.159	**0.2197**	0.0292	-0.035	0.0012	0.0206	-0.019	-0.019	0.0952	-0.058	0.089	0.033
Length of internodes (cm)	0.167	0.151	0.1123	0.066	0.282	0.316	0.204	-0.016	0.0379	**0.2851**	-0.169	-0.116	0.1143	-0.051	0.0223	0.0153	-0.730	0.026	0.109
Days to 50% flowering (days)	-0.188	-0.130	-0.112	-0.149	-0.224	-0.229	-0.16	0.007	-0.0576	-0.2102	**0.3526**	0.2948	-0.301	-0.008	-0.022	0.0527	0.0353	-0.02	-0.29
Days to first picking (days)	0.432	0.437	0.410	0.290	0.364	0.415	0.383	-0.030	-0.0035	0.2504	-0.512	**-0.613**	0.7092	0.0498	-0.134	-0.020	0.0001	0.229	-0.33
Fruiting span (days)	0.131	0.134	0.126	0.061	0.117	0.129	0.118	0.003	0.0173	0.0740	-0.157	-0.213	**0.1846**	0.0113	-0.043	-0.010	-0.006	-0.08	0.398
Length of fruit (cm)	0.084	-0.036	0.011	-0.176	-0.217	-0.214	0.023	-0.309	0.0868	0.1773	0.0232	0.0796	-0.060	**-0.981**	-0.722	03870	0.1194	-0.21	-0.05
Diameter of fruit (cm)	0.308	0.211	0.001	1.271	0.952	0.744	0.289	-0.450	-0.1779	0.1611	-0.128	0.4513	-0.482	1.5138	**2.0553**	-0.289	-0.654	-0.17	0.063
Weight of fruit (g)	0.185	0.046	-0.095	0.263	0.128	0.097	-0.16	0.230	-0.3004	-0.0371	-0.103	-0.023	0.0399	0.2734	0.0977	**-0.693**	0.1086	-0.20	0.267
Number of seeds per fruit	0.304	-0.24	0.0020	0.056	-0.129	-0.241	0.030	0.393	-0.1875	-0.1805	0.0705	-0.001	-0.002	-0.085	-0.224	-0.110	**0.7051**	0.034	-0.04
Number of fruits per plant	-0.517	-0.710	0.844	-0.556	-0.471	-0.449	-0.62	-0.016	-0.4473	-0.1021	0.0805	0.4107	-0.487	-0.245	0.0955	-0.327	-0.052	**-1.09**	-0.16

Residual effect : 0.475

Table 4.5b Phenotypic path coefficients showing direct and indirect effects of different characters on fruit yield per plant

characters	Plant height at 30 DAS	Plant height at 60 DAS	Plant height at 90 DAS	No. of branches per plant at 30 DAS	No. of branches per plant at 60 DAS	No. of branches at 90 DAS	No. of leaves per plant	No. of nodes to first flower	Flowering nodes on main stem	Length of internodes	Days to 50% flowering (days)	Days to first picking (days)	Fruiting span (days)	Length of fruit (cm)	Diameter of fruit (cm)	Weight of fruit (g)	No. of seeds per fruit	No. of fruits per plant	Yield per plant (g)
Plant height at 30 DAS (cm)	**0.1235**	0.0820	0.072	0.0426	0.059	0.0708	0.0389	-0.0125	0.0141	0.0483	-0.055	-0.0660	0.0693	-0.004	0.0144	-0.0158	-0.048	0.032	0.3485
Plant height at 60 DAS (cm)	0.2212	**0.3332**	0.299	0.1207	0.200	0.2135	0.1800	0.0014	-0.0509	0.1224	-0.100	-0.1819	0.1920	0.007	0.0346	0.0067	-0.010	0.131	0.4735
Plant height at 90 DAS (cm)	0.0892	0.1376	**0.153**	0.0525	0.080	0.0854	0.0877	0.0181	-0.0182	0.0427	-0.035	-0.0766	0.0767	0.002	00006	0.0106	0.0037	0.067	0.4309
No. of branches per plant at 30 DAS	-0.0440	-0.0462	-0.043	**-0.1277**	-0.061	-0.0496	-0.0269	0.0035	0.0524	-0.0200	0.021	0.0067	-0.026	-0.017	-0.0307	0.0205	-0.002	0.002	0.1064
No. of branches per plant at 60 DAS	0.0651	0.0815	0.071	0.0652	**0.135**	0.1214	0.0673	-0.0132	-0.0139	0.0350	-0.047	-0.0383	0.0455	0.002	0.0300	-0.0077	-0.007	0.038	0.3152
No. of branches per plant at 90 DAS	-0.041	-0.046	-0.040	-0.0280	-0.064	**-0.0721**	-0.0312	0.0045	0.0055	-0.0230	0.026	0.0259	-0.030	0.003	-0.0076	0.0069	0.0131	-0.019	0.3127
No. of leaves per plant	0.080	0.137	0.146	0.0156	0.126	0.1103	**0.2548**	0.0589	-0.0383	0.0961	-0.055	-0.0428	0.515	0.013	-0.0054	0.0247	0.0075	0.111	0.2822
No. of nodes to first flower	0.012	-0.005	-0.015	0.0035	0.012	0.0079	-0.0294	**-0.127**	0.0451	-0.0170	0.0013	0.0105	0.0023	-0.005	0.0035	0.0259	-0.035	-0.009	-0.186
Flowering nodes on main stem	0.014	-0.019	-0.014	-0.0513	-0.0128	-0.0096	-0.0188	-0.0444	**0.1252**	0.0009	-0.017	-0.0018	-0.010	-0.011	-0.0032	0.0374	-0.027	0.032	0.0139
Length of internodes (cm)	-0.043	-0.041	-0.031	-0.0175	-0.0289	-0.0358	-0.0422	-0.0150	-0.0008	**-0.1120**	0.040	0.0200	-0.022	0.019	0.0024	-0.0100	0.0108	-0.020	0.0989
Days to 50% flowering (days)	-0.018	-0.012	-0.009	-0.0071	-0.0147	-0.0156	-0.0091	-0.0004	-0.0059	-0.0152	**0.042**	0.0220	-0.023	-0.001	0.0006	0.0017	0.0032	0.009	-0.240
Days to first picking (days)	0.031	0.032	0.029	0.0031	0.0165	0.0211	0.0098	0.0048	0.0008	0.0105	-0.030	**-0.0587**	0.047	-0.007	-0.0068	-0.0066	-0.014	0.017	-0.260
Fruiting span (days)	0.036	0.037	0.032	0.0136	0.0217	0.0270	0.0131	-0.0012	-0.0054	0.0130	-0.035	-0.0520	**0.064**	-0.003	-0.0025	-0.045	-0.003	0.014	0.303
Length of fruit (cm)	0.001	-0.001	-0.007	-0.0059	-0.0008	0.0002	-0.0023	-0.0020	0.0042	0.0077	0.001	0.0054	0.002	**-0.04**	-0.0140	0.0033	0.0014	0.001	-0.041
Diameter of fruit (cm)	0.003	0.003	0.001	0.0072	0.0066	0.0032	-0.0006	-0.0083	-0.0008	-0.006	0.004	0.0035	-0.001	0.0095	**0.0299**	-0.0028	-0.009	0.000	0.028
Weight of fruit (g)	-0.020	0.0033	0.011	-0.0262	-0.0092	-0.0157	0.0158	-0.0333	0.0487	-0.014	0.006	0.0184	-0.011	-0.012	-0.0152	**0.1633**	0.0037	0.019	0.194
No. of seeds per fruit	-0.024	-0.0019	0.0015	0.0013	-0.0034	-0.0113	0.0018	0.0173	-0.0138	-0.010	0.0047	0.0015	-0.003	-0.002	-0.0192	0.0014	**0.062**	-0.001	-0.023
No. of fruits per plant	-0.137	-0.2054	-0.230	0.0087	-0.1483	-0.1384	-0.2275	-0.0373	-0.1341	-0.094	-0.105	0.1544	-0.119	0.012	-0.0147	-0.0609	0.0103	**-0.51**	-0.097

Residual effect : 0.729

Indirect effects

Plant height at 30 DAS (cm)

Plant height at 30 DAS expressed positive indirect effect through days to first picking (0.070), days to 50% flowering (0.055), number of seeds per fruit (0.043), weight of fruit (0.026) and number of nodes to first flower (0.021). However, negative indirect effects were observed through number of branches per plant at 90 DAS (-0.097), number of branches per plant at 60 DAS (-0.088), fruiting span (-0.073), number of branches per plant at 30 DAS (-0.070) and plant height at 60 DAS (-0.068).

Plant height at 60 DAS (cm)

Plant height at 60 DAS showed the highest positive indirect effect through days to first picking (0.938), days to 50% flowering (0.487), number of flowering nodes on main stem (0.265) and weight of fruit (0.088). Negative indirect effect for plant height at 60 DAS were measured through number of leaves per plant (-1.416), number of branches per plant at 90 DAS (-1.352), number of branches per plant at 60 DAS (-1.347), plant height at 90 DAS (-1.233), number of branches per plant at 30 DAS (-0.975) and fruiting span (-0.956).

Plant height at 90 DAS (cm)

The positive indirect effect of plant height at 90 DAS exhibited through number of leaves per plant (4.119), plant height at 60 DAS (3.527), number of branches per plant at 90 DAS (3.479), number of branches per plant at 60 DAS (3.334), number of fruits per plant (2.903), number of branches per plant at 30 DAS (2.664), fruiting spans (2.584) and plant height at 30 DAS (2.281). While, the negative indirect effect with higher magnitude were observed through days to first picking (-2.517), days to 50% flowering (-1.197) and number of flowering nodes on main stem (-0.590).

Number of branches per plant at 30 DAS

The indirect positive effects were observed for number of branches per plant at 30 DAS through number of flowering nodes on main stem (0.424), days to first picking (0.330), days to 50% flowering (0.295) and weight of fruit (0.264). However, negative indirect effects were expressed through number of branches per plant at 60 DAS (-0.856), number of branches per plant at 90 DAS (-0.738), number of leaves per plant (0.643), plant height at 60 DAS (0.517), plant height at 90 DAS (0.494), plant height at 30 DAS (0.490) and diameter of fruit (-.431).

Number of branches per plant at 60 DAS

Number of branches per plant at 60 DAS revealed highest positive indirect effect through days to 50% flowering (1.205), days to first picking (1.123), number of flowering nodes on main stem (0.677), weight of fruit (0.351) and number of seeds per fruit (0.345). Indirect negative effect were observed through number of branches per plant at 30 DAS (-2.319), number of leaves per plant (-2.200), plant height at 60 DAS (-1.935), number of branches per plant at 90 DAS (-1.912), length of internode (-1.871), plant height at 90 DAS (-1.673), plant height at 30 DAS (-1.672) and fruiting span (-1.202).

Number of branches per plant at 90 DAS

The positive indirect effect were observed for number of branches per plant at 90 DAS through number of leaves per plant (1.184), length of internode (1.130), number of branches per plant at 30 DAS (1.076), number of branches per plant at 60 DAS (1.028), plant height at 60 DAS (1.045), plant height at 30 DAS (0.987) and plant height at 90 DAS (0.940). While, indirect negative effect showed through days to first picking (-0.688), days to 50% flowering (-0.663), number of seeds per fruit (-0.347), number of flowering nodes on main stem (-0.243) and weight of fruit (-0.143).

Number of leaves per plant

Number of leaves per plant expressed positive indirect effect through days to first picking (0.155) and days to 50% flowering (0.116). Indirect negative effect revealed through number of branches per plant at 60 DAS (-0.289), number of branches per plant at 90 DAS (-0.289), plant height at 90 DAS (-0.272), plant height at 60 DAS (-0.268), number of branches per plant at 30 DAS (-0.229), length of internode (-0.178) and fruiting span (-0.159).

Number of nodes to first flower

Number of nodes to first flower exhibited positive indirect effect with number of flowering nodes on main stem (0.267), weight of fruit (0.122) and diameter of fruits (0.080). While, indirect negative effect was shown through number of seeds per fruit (-0.205), number of branches per plant at 30 DAS (-0.199), number of leaves per plant (-0186), length of fruit (-0.116) and number of branches per plant at 90 DAS (-0.110).

Number of flowering nodes on main stem

Number of flowering nodes on main stem showed highest positive indirect effect through weight of fruit (0.95), number of fruits per plant (0.089), length of internode (0.029) and plant height at 30 DAS (0.024). However, negative indirect effects were observed through number of nodes to first flower (-0.159), number of branches per plant at 30 DAS (-0.133), number of branches per plant at 60 DAS (-0.078), number of seeds per fruit (-0.058) and number of branches per plant at 90 DAS (-0.052).

Length of internodes (cm)

The indirect positive effect were observed for internodal length through number of branches per plant at 90 DAS (0.316), number of branches per plant at 60 DAS (0.282), number of leaves per plant

(0.204), plant height at 30 DAS (0.167), plant height at 60 DAS (0.151) and fruiting span (0.114). Negative indirect effects for internodal length were measured through days to 50% flowering (-0.169), days to first picking (-0.116), length of fruit (-0.051) and number of nodes to first flower (-0.016).

Days to 50% flowering (days)

Days to 50% flowering expressed positive indirect effect through days to first picking (0.294), weight of fruit (0.052) and number of seeds per fruit (0.035). However, negative indirect effects were expressed through number of branches per plant at 90 DAS (-0.229), number of branches per plant at 60 DAS (-0.224), length of internode (-0.210), plant height at 30 DAS (-0.188), number of leaves per plant (-0.165), number of branches per plant at 30 DAS (-0.149), plant height at 60 DAS (-0.130) and plant height at 90 DAS (-0.112).

Days to first picking (days)

Days to first picking exhibited positive indirect effect through fruiting span (0.709), plant height at 60 DAS (0.437), plant height at 30 DAS (0.432), number of branches per plant at 90 DAS (0.415), plant height at 90 DAS (0.410), number of leaves per plant (0.383) and number of branches per plant at 60 DAS (0.364). However, negative indirect effects were revealed through days to 50% flowering (-0.512), diameter of fruit (-0.134), number of nodes to first flower (-0.031) and weight of fruit (-0.023).

Fruiting span (days)

The indirect positive effect of fruiting span was expressed through plant height at 30 DAS (0.136), plant height at 60 DAS (0.134), number of branches per plant at 90 DAS (0.129), plant height at 90 DAS (0.126), number of leaves per plant (0.118) and number of branches per plant at 60 DAS (0.117). However, negative indirect effects were

observed through days to first picking (-0.213), days to 50% flowering (-0.157), diameter of fruit (-0.043) and weight of fruit (-0.010).

Length of fruit (cm)

Length of fruit showed positive indirect effects through weight of fruit (0.387), number of seeds per fruit (0.119) and length of internode (0.177). Whereas, negative indirect effects were recorded through diameter of fruit (-0.722), number of nodes to first flower (-0.309), number of fruit per plant (-0.219), number of branches per plant at 60 DAS (-0.217), number of branches per plant at 90 DAS (-0.214) and number of branches per plant at 30 DAS (-0.176).

Diameter of fruit (cm)

Diameter of fruit exhibited positive indirect effect through length of fruit (1.513), number of branches per plant at 30 DAS (1.271), number of branches per plant at 60 DAS (0.952), number of branches per plant at 90 DAS (0.744), days taken to first picking (0.451), plant height at 30 DAS (0.308) and number of leaves per plant (0.289). Indirect negative effects revealed through number of seeds per fruit (-0.654), fruiting span (-0.482), number of nodes to first flower (-0.450), weight of fruit (-0.289) and number of fruits per plant (-0.179).

Weight of fruit (g)

Weight of fruit showed positive indirect effects through length of fruit (0.273), number of branches per plant at 30 DAS (0.263), number of nodes to first flower (0.230), plant height at 30 DAS (0.185), number of branches per plant at 60 DAS (0.128) and number of seeds per fruit (0.108). However, negative indirect effects were exhibited through number of flowering nodes on main stem (-0.300), number of fruits per plant (-0.207) and number of leaves per plant (-0.167).

Number of seeds per fruit

Number of seeds per fruit expressed positive indirect effect through number of nodes to first flower (0.393), days to 50% flowering (0.070), number of branches per plant at 30 DAS (0.056), number of fruit per plant (0.034), number of leaves per plant (0.030). Indirect negative effect was observed through plant height at 30 DAS (-0.340), number of branches per plant at 90 DAS (-0.241), diameter of fruit (-0.224), number of flowering nodes on main stem (-0.187), length of internode (-0.180), number of branches per plant at 60 DAS (-0.129) and weight of fruit (-0.110).

Number of fruits per plant

Positive indirect effects were observed for number of fruits per plant through days to first picking (0.410), diameter of fruit (0.095) and days to 50% flowering (0.080). However, indirect negative effect were shown through plant height at 90 DAS (-0.844), plant height at 60 DAS (-0.710), number of leaves per plant (-0.627), number of branches per plant at 30 DAS (-0.556) and plant height at 30 DAS (-0.517).

An overall observation of path coefficient analysis of fruit yield per plant with its components revealed that the characters plant height, diameter of fruit, number of branches per plant at 90 DAS, number of seeds per fruit, days to 50% flowering, length of internode and number of flowering nodes on main stem) played an important role in determining the fruit yield per plant in okra.

Identification of better genotypes under Jabalpur condition

In present investigation the better genotypes in relation to yield under Jabalpur condition was genotype Okra-hy-10 with 303.00g yield per plant followed by Okra-hy-6 (290.33g) and 10/Okra-hy-1(282.67).

Okra-hy-10

Genotype Okra-hy-10 had 160cm plant height and 4.13 branches per plant at maturity. It takes 45 days to 50% flowering and first fruit grown at 4^{th} nodes. It's fruits were 17.38cm with 1.74cm diameter and 16.24g weight. It had 303g yield per plant.

DISCUSSIONS

The experimental findings of the present investigation “Evaluation of genetic variability, correlation study and path analysis of okra [*Abelmoschush esculentus* (L.) Moench] under Jabalpur condition” have been discussed on the following heads in the light of the available literature.

5.1 Analysis of variance

5.2 Genetic variability

5.2.1 Mean performance

5.2.2 Coefficient of variation

5.2.3 Heritability and genetic advance

5.3 Correlation coefficient analysis

5.4 Path coefficient analysis

The efficiency of selection depends on the extent of genetic variability present in the population. Yield is regarded as a complex character and influenced by many component traits both in positive and negative direction. Therefore, the use of biometrical techniques such as correlation and path analysis provide useful information for selection.

5.1 Analysis of variance

Analysis of variance for different characters under study revealed that mean differences due to genotypes were highly significant for all the characters. Presence of such variability in the population under study is the ultimate result of variability in the genetic constitution of various individuals. Such variability is desirable and can be utilized for developing new genotypes in okra. The progress in breeding programme depending upon availability of genetic variability and understanding this variability provides many avenues for genetic improvement of crop without which neither the improvement in an

exiting line nor development of new line is feasible, more the variability, higher are the chance of improvement of crop species. The findings were quite similar to the findings of Verma *et al* (2004), Naidu *et al*. (2007), Akotkar *et al.* (2010) and Shantha kumar and Salimath (2010).

5.2 Genetic variability

5.2.1 Mean performance

The mean performance of the genotypes (Table 4.2a) revealed a wide range of variability for all the traits. The variation was highest for yield per plant (232.67-303g), plant height at 60 DAS (91.60-148.67cm), plant height at 30 DAS (19.13-62.46cm), plant height at 90 DAS (144.33-187cm), number of seeds per fruit (54.86-74.26), number of leaves per plant (28.47-38.26), number of fruits per plant (19.40-26.60), weight of fruit (12.09-17.88g) and length of internode (11.67-17.30 cm). These findings are supported by the findings of Bendale *et al*. (2003), Kuwar *et al*. (2003), Kumar and Kumar (2005), Naidu *et al* (2007), Singh and Annapurna (2011), Senapati, *et al*.(2011).

Plant height at 30, 60 and 90 DAS (cm)

Significant differences were recorded among the genotypes with regard to the plant height at 30, 60 and 90 days after sowing. Maximum plant height was recorded in Pusa sawani at 30 DAS, SOH-152 at 60 DAS and Okra-hy-5 at 90 DAS. While the genotype 10/okra-hy-9 had minimum plant height at 30 DAS and 60 DAS and okra-hy-5 had minimum plant height at 90 DAS.

All the treatments were provided similar experimental condition. Variation in plant height was due to inherent genetic make up of the genotypes which in some way influence this morphological expression through the activity of endogenous growth regulator. The variation for plant height was also reported by Dhankar and Dhankar (2002), Bendale *et al.* (2003), Hamed *et al*. (2003), Kuwar *et al*. (2003), Kumar

and Kumar (2005), Naidu *et al.* (2007), Singh and Annapurna (2011) and Senapati, *et al*.(2011).

Branches per plant at 30, 60 and 90 DAS

Investigation on number of branches per plant (at 30, 60 and 90 DAS) indicated that all the genotypes differed significantly. Maximum number of branches per plant was recorded in SOH-152 at all the crop growth stages. While, the lowest number of branches were observed in 10/okra-hy-2 at 30 and 90 DAS and 10/okra-hy-4 at 60 DAS. These finding are in agreement with Bendale *et al.* (2003), Hamed *et al*. (2003), Kuwar *et al*. (2003), Verma *et al*. (2004), Kumar and Kumar (2005), Singh and Annapurna (2011).

Number of leaves per plant

Significant differences were recorded among the genotype with regard to number of leaves per plant. Maximum leaves per plant were recorded in SOH-152. However, minimum number of leaves per plant was observed in genotype 10/okra-hy-1. Variation in number of leaves was also reported by Singh and Annapurna (2011).

Number of nodes to first flower

Significant differences were recorded for number of nodes to first flower amongst the genotypes. Highest number of nodes to first flower was found in the genotype SOH-152. While, lowest number of nodes to first flower was exhibited in genotype okra-hy-7. Similar variation was also reported by Bendale *et al*. (2003) and Hamed *et al*. (2003).

Number of flowering nodes on main stem

Higher number of flowering nodes on main stem was observed in the genotype Arka Anamika. Whereas, lowest was depicted in the genotype SOH-152. Similar observation have also been reported by

Sood (1999), AL-Ghzawi *et al*. (2003), Bendale *et al*. (2003), Hamed *et al*. (2003) and Singh and Annapurna (2011).

Length of internodes (cm)

In the present findings, length of internode showed significant differences amongst the genotypes. Bhindi MHOK-12 gave maximum internodal length while 10/okra-hy-1 had lowest internodal length. Variation in internodal length was due to the inherent genetic makeup of genotypes, which may be due to activity of endogenous growth regulators. These findings are also supported by the findings of Bendale *et al*. (2003).

Days to 50 percent flowering (days)

Significant differences were recorded between the genotypes with regards to the days taken to 50% flowering. Check variety SOH-152 observed minimum days for 50 per cent flowering and maximum days taken to 50 percent flowering was observed in the genotype 10/okra-hy-5. Similar results have been reported by Sood (1999) and Singh and Annapurna (2011).

Days to first picking (days)

First picking of marketable fruits (days) differed significantly. The minimum number of days taken to first picking was seen in the genotype SOH-152 whereas, the late picking was observed in two genotypes viz., HOK-152 and 10/okra-hy-9. These finding are in agreement with the findings of Bendale *et al.* (2003).

Fruiting span (days)

Fruiting span differed significantly amongst the genotypes. Genotype SOH-152 was recorded the maximum days for fruiting span and genotype HOK-152 recorded minimum fruiting span. Similar results have been reported by Sood (1999) and Bendale *et al.* (2003).

Length of fruit (cm)

Significant differences in length of fruit indicate that a considerable variability was present for this trait, which can be exploited for future breeding programme. The longest fruit length was observed in the genotype okra-hy-8 while, smallest was recorded in the genotype Pusa Sawani. Differences for fruit length have also been reported by Farghali *et al*. (1994), Prakash *et al*. (2001), AL-Ghzawi *et al*. (2003), Bendale *et al*. (2003), Kuwar *et al*. (2003) and Singh and Annapurna (2011).

Diameter of fruit (cm)

Diameter of fruit shows significant variation. Maximum diameter of fruit was recorded in the genotype okra-hy-10. However, minimum diameter of fruit was observed in the genotype 10/okra-hy-8. Similar results have been obtained by Farghali *et al*. (1994), Kuwar *et al*. (2003) and Singh and Annapurna (2011).

Weight of fruit (g)

The variation in fruit weight ranged between 12.09 to 17.88 g and the average was 15.39 g. Maximum weight of fruit was observed in 10/okra-hy-2 and minimum in HOK-152. The similar results are in agreement with Farghali *et al*. (1994), Patil *et al*.(1996), Sood (1999), Prakash *et al*. (2001), Bendale *et al*. (2003), Kuwar *et al*. (2003), Naidu *et al* (2007) and Singh and Annapurna (2011).

Number of seeds per fruit

Genotype10/okra-hy-6 had highest number of seeds per fruit and Bhindi No-10 produced lowest number of seed per fruit. Similar results were also reported by Prakash *et al*. (2001), AL-Ghzawi *et al*. (2003), Bendale *et al*. (2003) and Kumar and Kumar (2005).

Number of fruits per plant

With regards to number of fruits per plant, highest number of fruits per plant was observed in Aarka Anamika where as lowest was depicted in 10/okra-hy-1. Similar findings have also been reported by Patil *et al*.(1996), Dhankar and Dhankar (2002), Bendale *et al*. (2003), Hamed *et al*. (2003), Kuwar *et al*. (2003), Kumar and Kumar (2005), Naidu *et al.* (2007) and Singh and Annapurna (2011).

Yield per plant (g)

Yield is a complex character and is determined by many genes and is largely influenced by environmental condition. Highest yielding genotype was okra-hy-10 while HOK-152 gave the lowest yield per plant. These findings are in agreement with the findings of Sood (1999), Dhankar and Dhankar (2002), AL-Ghzawi *et al*. (2003), Bendale *et al*. (2003), Hamed *et al*. (2003), Kuwar et *al*. (2003), Verma *et al*. (2004), Naidu *et al.* (2007), Singh, and Annapurna (2011) and Senapati, *et al*. (2011).

5.2.2 Coefficient of variation

Significant estimates of genetic variability for fruit yield and its components were observed for all the characters studied. In general, the values of phenotypic coefficient of variation were of higher magnitude than that of genotypic coefficient of variation for all the characters showing that the environment had an important role in influencing the expression of the characters. These findings are in agreement with the findings of Bendale *et al*. (2003) and Singh *et al.* (2007).

Highest phenotypic coefficient of variation was observed for number of branches per plant at 60 DAS followed by number of branches per plant at 90 DAS, number of branches per plant at 30 DAS and plant height at 30 DAS. Lowest phenotypic coefficient of variation

was observed for days to 50% flowering followed by days to first picking, fruiting span, length of fruits and number of nodes to first flower. High value of genotypic coefficient of variation (GCV) suggested greater phenotypic and genotypic variability among the genotypes and responsiveness of the attributes for making further improvement by selection. However, low estimates of phenotypic (PCV) and genotypic coefficient of variation GCV were noted for number of nodes to first flower which indicate that there is limited scope for improvement.

Similar results have been reported by Vijay and Manohar (1990) for number of branches per plant, Deo *et al.* (1996) for plant height and number of branches, Bindu *et al.* (1997), Dhall *et al.* (2003) Bali *et al.* (2004), Singh and Singh (2006), Singh *et al.* (2006) and Narayan *et al.* (2006) reported high PCV for plant height and number of branches per plant and low PCV for days taken to 50% flowering and Singh *et al.* (2007) for plant height.

5.2.3 Heritability and genetic advance

Heritability

Heritability which denotes the proportion of genetically controlled variability is very important biometrical tool for guiding plant breeder for adoption of appropriate breeding procedures. Higher heritability in broad sense is helpful in identifying appropriate characters for selection. It was partitioned as very high (> 90%), high (70-90%) medium (50-70%) and low (<50%). Heritability ranged from 19.92% for number of nodes to first flower to 97.52% for yield per plant.

Result indicated that the heritability (broad sense) was found to be very high for yield per plant, plant height at 30 DAS, plant height at 60 DAS and plant height at 90 DAS. However, it was recorded to be high for number of seeds per fruit and number of flowering nodes on main stem. The results were in close proximation to that of Vijay and Manohar (1990) for plant height, Sood *et al.* (1995) for plant height and

number of flowering nodes on main stem, Bindu *et al.* (1997) for plant height, Paiva *et al.* (1998) for plant height, Bali *et al.* (2004) for number of seeds per fruit and yield per plant, Patro and Ravisankar (2004) for yield per plant, Verma *et al*. (2004) for number of seeds per fruit, Indurani and Veerargavathatham (2005) for plant height and yield per plant, Singh and Singh (2006) for yield per plant, Singh *et al.* (2006) for number of seeds per fruit , Sunil *et al.* (2007) for plant height, number of flowering nodes on main stem and yield per plant, Pal *et al.* (2010), Ramanjinappa *et al.* (2011) for plant height and yield per plant. Higher values of heritability (broad sense) of these characters expressed that they were least influenced by environmental modification. It reflected that the phenotypes were the representative of their genotypes and selection based on phenotypic performance would be reliable.

Days to 50% flowering, days to first picking, diameter of fruit, fruiting spans and length of internodes were exhibited moderate heritability which indicated that selection based on phenotypic performance would be rewarding.

A low estimate of heritability was recorded for length of fruits, number of branches per plant at 90 DAS, number of branches per plant at 60 DAS, number of fruits per plant, weight of fruits, number of leaves per plant, number of branches per plant at 30 DAS and number of nodes to first flower. This is indicative of the fact that characters are rather more influenced by the environment and may not respond much to selection. The findings are in agreement with findings of Sunil *et al.* (2007) for length of fruits.

Heritability however indicates only the effectiveness with which selection of genotype can be based on phenotypic performance, but fail to indicate the genetic progress. Heritability estimates along with genetic gains are more effective and reliable in predicting the improvement through selection (Johnson *et al.* 1955.). Estimates of

genetic advance predict the extent of improvement that can be achieved for improving the different characters.

Genetic advance

In the present study, the characters namely plant height at 30 DAS followed by number of seeds per fruit, branches per plant at 60 DAS, number of branches per plant at 90 DAS and plant height at 60 DAS were recorded higher value of genetic advance as percentage of mean. These findings were similar to as reported by Jeypandi and Balakrishnan (1992), Patil *et al*. (1996), Panda and Singh (1997), Indurani and Veerargavathatham (2005), Pal *et al.* (2010) and Ramanjinappa *et al.* (2011) for plant height, Chandra *et al*. (1996) and Verma *et al*. (2004) for plant height and number of seed per fruit, Bali *et al.* (2004) for number of seed per fruit. While, moderate value observed for number of branches per plant at 30 DAS followed by yield per plant, length of internodes, plant height at 90 DAS and number of flowering nodes on main stem. These findings were similar with findings of Singh *et al.* (2007), Sunil *et al.* (2007) for number of flowering nodes on main stem, length of internode and yield per plant. However, the estimates were low for weight of fruits, number of fruits per plant, number of leaves per plant, diameter of fruits, fruiting spans, length of fruits, days to first picking, days to 50% flowering and number of nodes to first flower. The findings were similar to as reported by Vijay and Manohar (1990) for length of fruit and diameter of fruit, Sunil *et al.* (2007) for plant height and length of fruit.

High heritability coupled with high genetic advance for trait plant height at 30 DAS, plant height at 60 DAS and number of seeds per fruit suggested the prepondance of additive genes. It also indicated higher response for selection of high yielding genotypes as these characters are governed by additive gene actions. This result was in close proximation to that of Jeypandi and Balakrishnan (1992), Chandra *et al*.

(1996), Panda and Singh (1997), Bali *et al.* (2004), Verma *et al*. (2004) Akotkar *et al.* (2010) and Nwangburuka *et al.(*2012).

High heritability supplemented with moderate genetic advances as percentage of mean were manifested by yield per plant, plant height at 90 DAS and flowering nodes on main stem which might be due to the action of additive gene controlling expression of traits hence, stratified phenotypic selection for their amenability can be brought about. The findings were in agreement to the findings of Sunil *et al.* (2007) for by yield per plant and flowering nodes on main stem.

Low estimates of heritability coupled with low genetic advances as percentage of mean were displayed by length of fruits followed by number of fruits per plant, weight of fruit, number of leaves per plant and no of nodes to first flower indicated that these characters was highly influenced by environmental effects and consequently selection for these traits may not be rewarding. The findings were similar to as reported by Sunil *et al.* (2007) for length of fruits

5.3 Correlation coefficient analysis

Correlation coefficients were estimated between yield and its components at genotypic, phenotypic and environmental levels to know the correlation among the characters. It provides information about the nature, extent and direction of selection pressure to be applied for practical consideration. In general, genotypic correlation coefficients were higher than the phenotypic one because of masking effect of genotypes for the expression of characters. Similar results have been reported by Niranjan and Mishra (2003).

Plant height at 30 DAS (cm)

Significant and positive correlation of plant height at 30 DAS was observed with plant height at 60 DAS, plant height at 90 DAS, fruiting spans, number of branches per plant at 60 DAS, length of internode,

yield per plant and number of branches per plant at 30 DAS, number of leaves per plant and number of fruit per plant. However, its Significant and negative association was observed with days to first picking, days to 50% flowering and number of seeds per fruit. Similar results have been reported by Gondane *et al.* (1995), Sood *et al*. (1995), Rajani and Manju (1997), Niranjan and Mishra (2003), Bendale *et al*.(2003), Narayan and Muldge (2004), Choudhary (2006), Magar, *et al*. (2009), Chaukhande *et al.* (2011), Ramanjinappa *et al.* (2011).

Plant height at 60 DAS (cm)

Plant height at 60 DAS showed Significant and positive association with plant height at 90 DAS, plant height at 30 DAS, number of branches per plant at 90 DAS, number of branches per plant at 60 DAS, fruiting spans, number of leaves per plant, days to first picking, yield per plant, number of fruit per plant and number of branches per plant at 30 DAS. However, significant and negative correlation observed with days to 50% flowering. The findings were similar to as reported by Gondane *et al.* (1995), Sood *et al.* (1995), Rajani and Manju (1997), Niranjan and Mishra (2003), Bendale *et al.*(2003), Narayan and Muldge (2004), Choudhary (2006), Magar *et al.* (2009), Chaukhande *et al.* (2011), Ramanjinappa *et al.* (2011).

Plant height at 90 DAS (cm)

A significant and positive correlation was shown by this trait with plant height at 60 DAS, plant height at 30 DAS, number of leaves per plant, number of branches per plant at 90 DAS, number of branches per plant at 60 DAS, fruiting spans, yield per plant, number of fruit per plant, number of branches per plant at 30 DAS and length of internode. Significant and negative correlation was observed with days to first picking. Similar results have been reported by Chantana *et al.* (1990), Gondane *et al*. (1995), Sood *et al*. (1995), Rajani and Manju (1997), Niranjan and Mishra (2003), Bendale *et al.*(2003), Narayan and Muldge

(2004), Ghosh (2005), Choudhary (2006), Magar *et al.* (2009), Chaukhande *et al.* (2011), Ramanjinappa *et al.* (2011).

Number of branches per plant at 30 DAS

Number of branches per plant at 30 DAS had significant and positive correlation with number of branches per plant at 60 DAS, number of branches per plant at 90 DAS, plant height at 60 DAS, plant height at 30 DAS, plant height at 90 DAS and diameter of fruit. This trait expressed significant and negative correlation with number of flowering nodes on main stem.

Number of branches per plant at 60 DAS

Significant and positive correlation showed by number of branches per plant at 60 DAS with number of branches per plant at 90 DAS, plant height at 60 DAS, plant height at 90 DAS, number of leaves per plant, number of branches per plant at 30 DAS, plant height at 30 DAS, fruiting spans, yield per plant, number of fruit per plant and length of internode. It revealed significant and negative correlation with days to 50% flowering and days to first picking. Similar results have been reported by Chantana (1990), Dash and Mishra (1995), Niranjan and Mishra (2003), Patro and Ravishankar (2004), Bhalekar *et al.* (2005), Choudhary (2006).

Number of branches per plant at 90 DAS

Number of branches per plant at 90 DAS exhibited significant and positive correlation with number of branches per plant at 60 DAS, plant height at 60 DAS, plant height at 30 DAS, plant height at 90 DAS, number of leaves per plant, fruiting spans, number of branches per plant at 30 DAS, length of internode and yield per plan and number of fruit per plant. However, it showed significant and negative correlation with days to 50% flowering and days taken to first picking. The findings were similar to as reported by Chantana (1990), Dash and Mishra

(1995), Niranjan and Mishra (2003), Patro and Ravishankar (2004), Bhalekar *et al.* (2005), Choudhary (2006).

Number of leaves per plant

Number of leaves per plant expressed significant and positive association with number of branches per plant at 30 DAS, plant height at 60 DAS, number of branches per plant at 60 DAS, number of fruit per plant, number of branches per plant at 90 DAS, length of internode, plant height at 30 DAS and yield per plant. It showed significant and negative association with days to 50% flowering. Similar results have been reported by Narayan and Muldge (2004),

Number of nodes to first flower

Number of nodes to first flower revealed significant and positive correlation with number of seeds per fruit. However, it's significant and negative association observed with number of flowering nodes on main stem and diameter of fruit.

Number of flowering nodes on main stem

Number of flowering nodes on main stem exhibited significant and positive correlation with weight of fruit and number of fruit per plant. However, significant and negative association observed with number of branches per plant at 30 DAS and number of nodes to first flower.

Length of internode (cm)

Length of internode expressed significant and positive correlation with plant height at 30 DAS, number of leaves per plant, plant height at 60 DAS, number of branches per plant at 90 DAS, plant height at 90 DAS, number of branches per plant at 60 DAS. It showed significant and negative correlation with days to 50% flowering.

Days to 50% flowering (days)

Significant and positive association observed by days to 50% flowering with days to first picking. However, it showed significant and negative association with fruiting spans, plant height at 30 DAS, number of branches per plant at 90 DAS, length of internode, number of branches per plant at 60 DAS**,** plant height at 60 DAS, number of leaves per plant and yield per plant. Similar results have been reported by Mandal and Dana (1994), Gondane *et al*. (1995), Verma *et al*. (2007).

Days to first picking (days)

Days to first picking revealed significant and positive correlation with plant height at 60 DAS and days to 50% flowering. This trait showed significant and negative correlation with fruiting spans, plant height at 30 DAS, plant height at 90 DAS number of branches per plant at 90 DAS**,** number of fruit per plant, number of branches per plant at 60 DAS and yield per plant.

Fruiting spans (days)

Significant and positive correlation expressed by fruiting spans with plant height at 60 DAS plant height at 30 DAS, plant height at 90 DAS, number of branches per plant at 90 DAS, number of branches per plant at 60 DAS and yield per plant. While, significant and negative correlation recorded with days to first picking, and days to 50% flowering. Similar results have been reported by Rajani and manju (1997), Niranjan and Mishra (2003), Ghosh (2005), Choudhary (2006).

Length of fruit (cm)

Length of fruit showed significant and positive correlation with diameter of fruit.

Diameter of fruit (cm)

Significant and positive correlation revealed by diameter of fruit with length of fruit. However, it showed significant and negative correlation with number of seeds per fruit and number of nodes to first flower.

Weight of fruit (g)

Weight of fruit showed significant and positive association with number of flowering nodes on main stem.

Number of seeds per fruit

Number of seeds per fruit expressed significant and positive correlation with number of nodes to first flower. While, significant and negative association recorded with plant height at 30 DAS and diameter of fruit.

Number of fruit per plant

Number of fruit per plant showed significant and positive association with number of leaves per plant, plant height at 90 DAS, plant height at 60 DAS, number of branches per plant at 60 DAS, number of branches per plant at 90 DAS and plant height at 30 DAS and number of flowering nodes on main stem. However, it showed significant and negative correlation with days to first picking.

Yield per plant (g)

Result revealed that the fruit yield per plant was positively associated with plant height at 60 DAS, plant height at 90 DAS, plant height at 30 DAS, number of branches per plant at 60 DAS and number of branches per plant at 90 DAS, fruiting spans and number of leaves per plant. Similar results have been reported by Chantana (1990), Dash and Mishra (1995), Niranjan and Mishra (2003), Patro and Ravishankar

(2004), Bhalekar *et al*. (2005), Choudhary (2006), Verma *et al.* (2007), Magar *et al.* (2009), Chaukhande *et al.* (2011) and Ramanjinappa *et al*. (2011).

5.4 Path coefficient analysis

Correlation coefficients are the indication of simple association between variables. In a biological system however, the relationship may exist in a very complex form. It is therefore, essential to study the relationship among variables in a comprehensive way. Path coefficient analysis is a powerful tool, which enables portioning of the given relationship in its further components. In other words, it take into account not only the relationship of component characters with the dependent characters, but simultaneously takes care of its relationship with other components also. Thus, it helps in understanding the causal system in a better may because it enables partitioning of the total correlation coefficients into direct and indirect effects of various characters.

In the present investigation path coefficient analysis was carried out for characters under study using genotypic and phenotypic coefficient and taking yield per plant as dependable variables, in order to see the causal factor and so as to identify the components which are responsible for producing fruit yield per plant.

Path coefficient analysis of different characters revealed that plant height at 90 DAS had the highest positive direct effect on fruit yield per plant followed by diameter of fruit, number of branches per plant at 90 DAS, number of seeds per fruit, days taken to 50% flowering, length of internode, number of flowering nodes on main stem, fruiting spans. These results are in close harmony with Choudhary and Sharma (1999), Niranjan and Mishra (2003), Narayan and Muldge (2004), Sureshbabu *et al.* (2004), Pawar (2005), Magar *et al.* (2009), and Ramanjinappa *et al.* (2011). The characters plant height, diameter of fruit, number of branches per plant at 90 DAS, number of seeds per

fruit, days taken to 50% flowering, length of internode and number of flowering nodes on main stem had correlation coefficient value at par with yield per plant and direct selection for these traits would result in higher breeding efficiency for improving fruit yield. Thus, these traits might be reckoned as the most important component traits for fruit yield per plant.

Characters like number of branches per plant at 60 DAS exhibited negative direct effect on fruit yield per plant followed by plant height at 60 DAS, number of fruit per plant, length of fruit, number of branches per plant at 30 DAS, weight of fruit, days taken to first picking, number of nodes to first flower, number of leaves per plant and plant height at 30 DAS but were positively associated to it. Similar results have been reported by Verma *et al.* (2007) and Saifullah, *et al*. (2010). This indicated that indirect effect was cause of correlation and the indirect causal factors are to be considered simultaneously for selection.

The indirect effect of number of leaves per plant was observed with fruit yield per plant in high magnitude followed by number of branches per plant at 60 DAS, number of branches per plant at 90 DAS, plant height at 60 DAS and plant height at 90 DAS. Similar results have been reported by Saifullah, *et al.* (2010).

An overall observation of path coefficient analysis of fruit yield per plant with plant height, diameter of fruit, number of branches per plant at 90 DAS, number of seeds per fruit, days taken to 50% flowering, length of internode and number of flowering nodes on main stem played an important role in determining the fruit yield per plant.

Genotype Okra-hy-10 was recorded the maximum yield per plant followed by Okra-hy-6, 10/Okra-hy-1, Pusa sawani, 10/Okra-hy-6 and SOH-152.Whereas, minimum yield per plant was recorded in HOK-152

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

6.1 Summary

The present investigation “Evaluation of genetic variability, correlation studies and path analysis of okra [*Abelmoschush esculentus* (L.) Moench] under Jabalpur condition” was carried out during kharif season of 2011-2012 at the Vegetable Research Farm, Department of Horticulture, College of Agriculture, J.N.K.V.V., Jabalpur (M.P.). Present investigation comprised twenty genotypes of okra sown in Randomized Complete Block Design with three replications to estimate the genetic variability, correlation and path coefficient analysis. Observations were recorded on five random competitive plants for nineteen growth and yield characters. The variance components and coefficient of variation were determined according to Burton (1952). The heritability in broad sense was calculated using the formula proposed by Allard (1960) and expected genetic advance was worked out as per Johson *et al.* (1955). The correlation coefficient and path coefficient was computed by the formula suggested by Miller *et al.* (1958) and Dewey and Lu (1959). On the basis of results, the present investigation is summarized as follows:

The mean differences due to genotypes were highly significant for all the characters. The genotype Okra-hy-10 recorded the maximum yield per plant (303.00g). The result revealed that the phenotypic coefficient of variation was higher than the corresponding genotypic coefficient of variation for all the traits which might be due to the interaction of the genotypes with the environment to some degree or other environmental factors influencing the expression of these characters.

The highest phenotypic coefficient of variation was observed for number of branches per plant at 60 DAS followed by number of

branches per plant at 90 DAS and number of branches per plant at 30 DAS. Lowest phenotypic coefficient of variation was observed for days to 50% flowering, days to first picking, fruiting span, length of fruits and number of nodes to first flower. The high value of GCV suggested greater phenotypic and genotypic variability among the genotypes and responsiveness of the attributes for making further improvement by selection. However, low estimates of PCV and GCV were noted for number of nodes to first flower which indicate that there is limited scope for improvement.

Heritability (broad sense) was found to be very high for yield per plant, plant height at 30 DAS, plant height at 60 DAS and plant height at 90 DAS. However, it was recorded high for number of seeds per fruit and number of flowering nodes on main stem. Days to 50% flowering, days to first picking, diameter of fruit, fruiting spans and length of internodes exhibited moderate heritability. A low estimate of heritability was recorded for length of fruit, number of branches per plant at 90 DAS, number of branches per plant at 60 DAS, number of fruits per plant, weight of fruit, number of leaves per plant, number of branches per plant at 30 DAS and number of nodes to first flower.

In present study, the characters viz., plant height at 30 DAS followed by number of seeds per fruit, branches per plant at 60 DAS, number of branches per plant at 90 DAS and plant height at 60 DAS recorded higher value of genetic advance as percentage of mean. While, moderate value was observed for number of branches per plant at 30 DAS followed by yield per plant, length of internodes, plant height at 90 DAS and number of flowering nodes on main stem. However, the estimates were low for weight of fruits, number of fruits per plant, number of leaves per plant, diameter of fruit, fruiting span, length of fruit, days to first picking, days to 50% flowering and number of nodes to first flower.

High heritability coupled with high genetic advance were recorded for trait plant height at 30 DAS, plant height at 60 DAS and number of seeds per fruit suggested that the prepondance of additive genes. High heritability supplemented with moderate genetic advances as percentage of mean were manifested by yield per plant, plant height at 90 DAS and flowering nodes on main stem which might be due to the action of additive gene. Low estimates of heritability coupled with low genetic advances as percentage of mean were displayed by length of fruits followed by number of fruits per plant, weight of fruit, number of leaves per plant and number of nodes to first flower indicating that these characters were highly influenced by environmental effects.

The phenotypic correlation coefficients were higher in magnitude than their corresponding genotypic one, indicating there by strong inherent association between different traits under studied.

Fruit yield per plant was found significantly and positively correlated with plant height at 60 DAS, plant height at 90 DAS, plant height at 30 DAS, number of branches per plant at 60 DAS, number of branches per plant at 90 DAS, fruiting span and number of leaves per plant. However, it showed significant and negative correlation with days to first picking and days to 50% flowering.

Path coefficient analysis of different characters revealed that plant height at 90 DAS had the highest positive direct effect on fruit yield per plant followed by diameter of fruit, number of branches per plant at 90 DAS, number of seeds per fruit, days to 50% flowering, length of internode, number of flowering nodes on main stem and fruiting span. Therefore, selection pressure on these characters may be given due importance for genetic improvement.

Characters like number of branches per plant at 60 DAS exhibited negative direct effect on fruit yield per plant followed by plant height at 60 DAS, number of fruit per plant, length of fruit, number of branches per plant at 30 DAS, weight of fruit, days taken to first picking, number

of nodes to first flower, number of leaves per plant and plant height at 30 DAS but were positively correlated to it except length of fruit, number of fruit per plant, days to first picking and number of nodes to first flower. This indicated that the indirect effect was the cause of correlation and the indirect causal factors are to be considered simultaneously for selection.

Conclusions

The mean differences due to genotypes were highly significant for all the characters which indicates existence of high genetic variability for all the character under study.

The PCV was higher than GCV for all the characters, high PCV and GCV was observed for branches per plant at 60 DAS followed by number of branches per plant at 90 DAS, number of branches per plant at 30 DAS and plant height at 30 DAS. Lowest phenotypic coefficient of variation was observed for days to 50% flowering followed by days to first picking, fruiting span, length of fruits and number of nodes to first flower, indicating greater diversity for these traits and their further improvement through selection.

Fruit yield per plant was found significantly and positively correlated with plant height at 60 DAS, 90 DAS and 30 DAS, number of branches per plant at 60 DAS and 90 DAS, fruiting span and number of leaves per plant. However, significant and negative correlation showed with days to first picking and days to 50% flowering.

High heritability coupled with high genetic advance were recorded for trait plant height at 30 DAS, plant height at 60 DAS and number of seeds per fruit suggested that the prepondance of additive genes.

An overall observation of path coefficient analysis of fruit yield per plant with its components revealed that the characters plant height, diameter of fruit, number of branches per plant at 90 DAS, number of

seeds per fruit, days to 50% flowering, length of internode and number of flowering nodes on main stem) played an important role in determining the fruit yield per plant in okra.

Suggestion for further work

1. The out standing genotypes should be tested in multilocational trials for judging their adaptability and superiority across the season as well as locations

2. Identified genotypes should also be evaluated for qualitative parameters.

3. Further study considering the characters having direct effect on fruit yield should be taken under consideration for yield components.

4. DNA finger printing may be used for differentiating the genotypes.

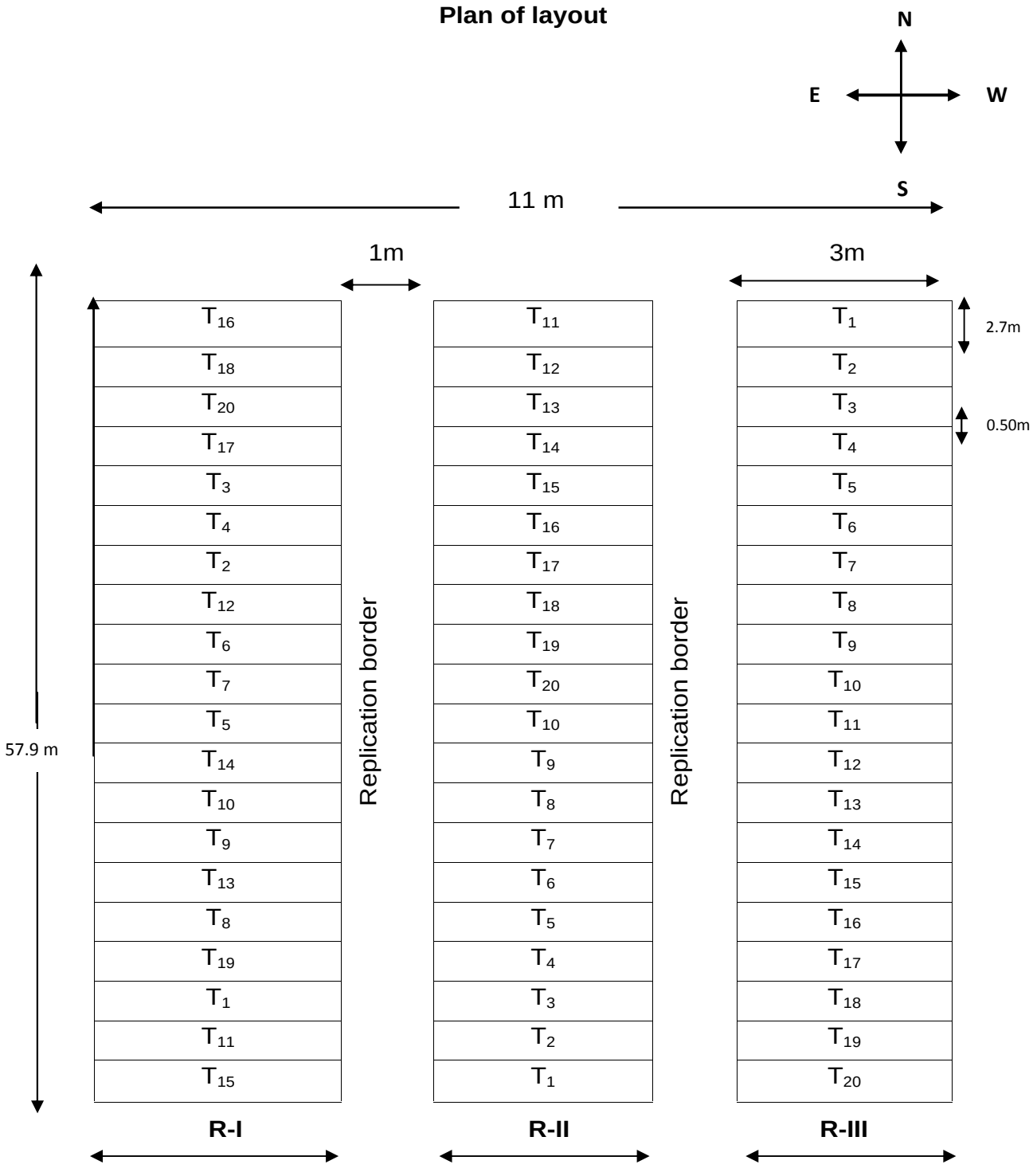

Fig.1. Plan of the layout of experimental plot

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ABSTRACT

Title of the thesis	:	"Evaluation of genetic variability, correlation studies and path analysis of okra [*Abelmoschus esculentus* (L.) Moench] under Jabalpur condition"
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ABSTRACT

The present investigation “Evaluation of genetic variability, correlation studies and path analysis of okra [*Abelmoschus esculentus* (L.) Moench] under Jabalpur condition” was carried out during kharif season of 2011-2012 at the Vegetable Research Farm, Department of Horticulture, College of Agriculture, J.N.K.V.V., Jabalpur (M.P.). The experimental material for the present investigation was comprised of 20 genotypes of okra. These genotypes were sown in Randomized Complete Block Design with three replication, to estimate the genetic variability, Correlation and Path coefficient analysis. Observations were recorded on the basis of five random competitive plants selected from each genotypes separately for morphological, phonological, yield and other parameters were evaluated as per standard procedure. The variance components and coefficient of variation were determined according to Burton (1952). The heritability (broad sense) and genetic advance was worked out by Hanson *et al*. (1956) and Johnson *et al*. (1955). Correlation coefficient and path coefficient was computed by the formula suggested by Miller *et al*. (1958) and Dewey and Lu (1959).

Analysis of variance revealed highly significant variance for all the characters. Presence of such variability in the population under study is the ultimate result of variability in the genetic constitution of various individuals.

High heritability coupled with high genetic advance for trait plant height at 30 DAS, plant height at 60 DAS and number of seeds per fruit suggested the prepondance of additive genes.

The correlation coefficient analysis revealed that fruit yield per plant was positively associated with plant height at 60 DAS, plant height at 90 DAS, plant height at 30 DAS, number of branches per plant at 60 DAS and number of branches per plant at 90 DAS, fruiting spans and number of leaves per plant.

An overall observation of path coefficient analysis of fruit yield per plant revealed that plant height, diameter of fruit, number of branches per plant at 90 DAS, number of seeds per fruit, days taken to 50% flowering, length of internode and number of flowering nodes on main stem played an important role in determining the fruit yield per plant.

Genotype Okra-hy-10 was recorded the maximum yield per plant (303.00g) which revealed that it was better genotype in relation to yield under Jabalpur condition.

VITA

The author of this thesis Meenakshee Dwivedi D/o Shri Narendra Kumar Dwivedi and Smt. Prabha Dwivedi was born on 5th July 1983 at Sidhi (M.P.). She passed her higher secondary school certificate examination from Saraswati Higher Secondary School Shahdol (M.P.) with 78.79%. She joined the college of Agriculture, Rewa Sub Campus of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) in the year 2006-07 and successfully completed the degree of B.Sc.(Ag.) during the year 2009-10 with 7.67 OGPA at 10 point scale.

For further study she got admission in M.Sc.(Horticulture) for specialization in Horticulture (Vegetable Science) at College of Agriculture, JNKVV, Jabalpur where she successfully completed the entire course requirement for Master's Degree with 7.80 OGPA at 10 point scale.

For the partial fulfillment of the Master's Degree programme she was allotted a research problem on **"Evaluation of genetic variability, correlation studies and path analysis of Okra [*Abelmoschus esculentus* (L.) Moench] under Jabalpur condition"** which was successfully conducted by her and being submitted in the form of this thesis.