EVALUATION OF OKRA [*Abelmoschus esculentus* (L.) Moench] GENOTYPES FOR YIELD AND RESISTANCE TO SHOOT AND FRUIT BORER, *Earias vittella* (Fab.)

by

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(2010-11-154)

THESIS

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COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM - 695 522

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Dedicated to Dr. Sunny K. Oommen

To the professors of Plant Breeding and Genetics

To my Dad, Mom and Sisters

DECLARATION

I hereby declare that this thesis entitled **"Evaluation of okra [*Abelmoschus esculentus* (L.) Moench] genotypes for yield and resistance to shoot and fruit borer, *Earias vittella* (Fab.)"** is a bonafide record of research done by me during the course of research and the thesis has not previously formed the basis for award of any degree, fellowship or other similar title, of any other University or society.

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CERTIFICATE

Certified that this thesis, entitled **"Evaluation of okra [*Abelmoschus esculentus* (L.) Moench] genotypes for yield and resistance to shoot and fruit borer, *Earias vittella* (Fab.)"** is a record of research work done independently by **Shrishail B. Duggi (2010 – 11 – 154)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associationship to him.

CERTIFICATE

We the undersigned members of the advisory committee of **Mr. Shrishail B. Duggi (2010- 11- 154)** a candidate for the degree of **Master of Science in Agriculture** agree that this thesis entitled **"Evaluation of okra [*Abelmoschus esculentus* (L.) Moench] genotypes for yield and resistance to shoot and fruit borer, *Earias vittella* (Fab.)"** may be submitted by **Mr. Shrishail B. Duggi (2010 - 11 – 154)**, in partial fulfillment of the requirement for the degree.

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Shrishail B. Duggi

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INTRODUCTION

1. INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench) is important vegetable of the tropical countries and most popular in India. Okra is mainly grown for its young immature fruits and consumed as a vegetable, raw, cooked or fried. Okra provides an important source of vitamins, calcium, potassium and other minerals which are often lacking in the diet of developing countries.

Okra belongs to family Malvaceae. There are 34 species under the genus *Abelmoschus.* Out of them *Abelmoschus esculentus* is the only species that is extensively cultivated. The crop is cultivated in an area of 0.35 million ha in India and the country ranks first in production with 3.5 million tonnes which accounts for 70% of the total world production (FAOSTAT, 2008).

Okra is attacked by several species of insect pests. The shoot and fruit borer *Earias vitella* Fabricius (Lepidoptera : Noctuidae) is an important pest which causes extensive damage to the crop. The larvae bore into the growing shoots, buds and tender fruits resulting in their shedding and consequently affecting the fruit quality and yield to considerable extent. Most of the present day cultivars are susceptible to this pest (Gupta and Yadav, 1978). Farmers usually adopt frequent sprays of chemical insecticides for controlling the pest. As okra fruits are harvested in frequent intervals, chemical protection may lead to accumulation of pesticide residues in the fruits and pose problems to the consumers.

Host plant resistance is a pest management tactic currently gaining importance. Development of crop varieties resistant to infestation by pests forms a principal component in Integrated Pest Management (IPM) systems (Dent, 1995).Even a low level of plant resistance can substantially reduce the dependence on chemical protection.

For any crop improvement programme, evaluation of germplasm is necessary to assess the existing variability for yield and component characters and to identify sources of resistance to pest and diseases. An understanding of inheritance of yield and its related traits, heritability, expected genetic advance and association between each component trait and yield is necessary for planning selection programmes aimed at yield improvement. Realizing the importance of developing high yielding okra genotypes with resistance to shoot and fruit borer the present investigation was undertaken with the following objectives.

1) Assessing the phenotypic and genotypic variability, heritability and genetic advance for yield and yield components.

2) To determine the phenotypic and genotypic correlation between the fruit yield and component characters in okra.

3) To identify sources of resistance to shoot and fruit borer and,

4) To identify high yielding okra genotypes with resistance to shoot and fruit borer, if available, among the accessions evaluated.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The present study aimed at evaluation of okra genotypes to identify high yielding shoot and fruit borer resistant genotypes. The literature pertinent to the study is presented under different headings.

2.1 GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE

A critical evaluation of genetic variability is a pre-requisite for initiating appropriate breeding procedures in crop improvement programmes. Phenotypic variability being influenced by environment needs to be partitioned into genetic and non-genetic components (East, 1916). Heritability and genetic advance are very important parameters in selection. Knowledge of heritability of traits is essential for the breeder, which helps in selection programme for improvement of traits to the extent possible (Robinson *et al.* 1949). Information on heritability coupled with genetic advance is more effective and reliable in predicting the effect of selection. High heritability together with genetic advance is indicative of additive genetic variance (Johnson *et al.* 1955). Genetic advance is a measure of expected genetic progress which helps to evaluate selection procedure.

Charles and Smith (1939) and Powar *et al*. (1950) used the estimates of environmental variance from the non-segregating population to separate the genetic variance from total variance. The relative magnitude of genetic diversity present in the material can be indicated as genotypic coefficient of variation and helps to compare the genetic variability present for different characters.

The study on genetic variability in 30 varieties of okra carried out by Singh and Singh (1979) revealed that number of pods per plant, fruit yield per plant, number of pod bearing branches and first fruiting node exhibited high variability, heritability, and genetic advance.

Mishra and Chonkar (1979) evaluated 18 varieties of okra and reported that components of variability, heritability and genetic advance were higher for branches per plant, pods per plant, seeds per pod and plant height.

Following a study on variability for seven characters in six okra varieties, Murthy and Bavaji (1980) reported appreciable variability for pod length, pod number and yield per plot. In addition, high heritability was also noticed for all the characters including, pod length, yield per plot and plant height. Highest genetic advance of 11.98% was noticed for pod length.

Vashistha *et al.* (1982) studied six characters in 25 genotypes of okra and observed high genotypic coefficient of variation (GCV) and high heritability for number of fruits per plant. High heritability coupled with high genetic advance was observed for plant height.

Palaniveluchamy *et al.* (1982) reported high heritability values for days to flowering, number of fruits per plant and pod weight.

Nair and Sheela (1985) reported high genotypic coefficient of variation for all the characters studied except fruit weight and stem girth. Heritability in broad sense ranged from 11.20 (pod weight) to 93.00 per cent (yield per plant). High heritability coupled with moderate genetic advance was observed for yield per plant and number of branches per plant.

Palve *et al.* (1985) evaluated 15 genotypes of okra and reported substantial variability for yield, number of pods per plant and days to flower. Relatively greater magnitude of GCV was also reported for length of fruit (22.10%) and yield (18.14%). Higher magnitude of heritability in association with expected genetic advance was observed for length of fruit (0.98 and 52.18%), number of fruits (0.50 and 32.43%), days to flowering (0.92 and 15.97%) and yield (0.43 and 24.6%). Plant height and number of internodes exhibited comparatively low variability but considerable amount of heritability and genetic advance.

Variability studies by Reddy *et al.* (1985) suggested higher genotypic and phenotypic variances for fruit yield per plant and plant height indicating wide variability. The GCV was greatest for fruit yield per plant and was minimum for days to flowering. The traits, number of branches and plant height also exhibited comparatively high GCV. The characters, days to flowering, fruit length and first fruiting node had low GCV. High heritability estimates were recorded for all the traits ranging from 90.9 per cent for fruit width to 99.9 per cent for fruit length. High genetic advance as percentage of mean along with high heritability was also observed for fruit yield per plant, number of branches and plant height.

Yadav (1985) studied six cultivars of okra and observed wide variation for plant height, yield per plant, seeds per pod and number of primary branches. High genotypic coefficients of variation, heritability and genetic advance were noticed for plant height, yield per plant and number of seeds per pod; whereas number of pods per plant and pod length showed moderately high value for genotypic coefficient of variation and heritability.

Genetic variability studies in okra by Balakrishnan and Balakrishnan (1988) revealed high phenotypic and genotypic variances for yield per plant followed by plant height and lower variances for number of ridges per fruit and fruit girth. The characters *viz.* plant height, number of fruits per plant, fruit weight, number of seeds per fruit and yield per plant recorded high heritability coupled with high genetic advance.

Kale *et al.* (1989) conducted experiments on 36 genotypes during kharif and summer seasons. Estimates for genetical parameters such as phenotypic and genotypic coefficients were found to be moderate to high for number of branches (34.89% and 28.67%), number of nodes (21.79% and 14.63%), internodal distance (23.15% and 14.99%), plant height (24.48% and 21.86%) and number of pods per plant (28.03% and 20.31%). The heritability estimates were also found to be moderate to high for plant height (77.17%), number of branches (67.17%), number of nodes (66.01%), internodal length (78.25%) and number of pods per plant (66.80%).

Studies conducted by Ariyo (1990) with 30 okra lines of diverse origin indicated high heritability estimates for fruit length and low for number of branches per plant, number of pods per plant and pod yield per plant.

Vijay and Manohar (1990) conducted studies on 55 genotypes of okra and found maximum coefficient of variation for pod yield per plant followed by number of pods per plant and days to fruit maturity. The traits, pod yield per plant, plant height and number of seeds per pod showed the highest genotypic and phenotypic variances. Highest heritability and genetic advance were observed for number of branches per plant and plant height.

Yadav and Chonkar (1991) reported that first fruiting node and number of branches per plant showed high narrow sense heritability, while moderate estimates were recorded for 50 per cent flowering and plant height. High phenotypic and genotypic variances were reported for yield per plant, plant height and number of seeds per pod.

Following genetic variability studies in okra, Jeyapandi and Balakrishnan (1992) reported high genotypic coefficient of variation for pod weight and number of pods per plant. High heritability and genetic advance were recorded for yield per plant, number of pods per plant, pod weight and pod length.

The study carried out by Mondal and Dana (1993) on nine yield components using ten okra genotypes revealed high genotypic coefficient of variation for branches per plant. High heritability was for number of seeds per fruit and genetic advance was highest for yield per plant.

The study conducted by Gondane and Lal (1994) revealed high level of variability for eleven yield components. Pods per plant, primary branches per plant and leaves per plant showed medium heritability coupled with high genetic advance.

The studies on variability, heritability and genetic advance in okra for ten characters conducted by Deo *et al.* (1996) revealed that pod yield, number of pods, plant height and number of branches per plant showed high genotypic and phenotypic coefficients of variation. Further, pod yield, plant height and number of seeds per pod recorded high heritability and genetic advance.

Studies conducted by Rao (1996) on 38 genotypes of okra for 11 characters, showed high genotypic and phenotypic variance for plant height and yield per plant. The traits, number of branches per plant, yield per plant, number of pods per plant and weight of pod recorded higher genotypic and phenotypic coefficients of variation, whereas lower estimates were recorded for plant height, days to first harvest and fruiting period. High heritability coupled with high genetic advance was observed for plant height and yield per plant.

Wide variability for plant height, number of branches, number of fruits, fruit weight and yield per plant was recorded in a study conducted by Mohamed and Anbu (1997) with 15 genotypes of okra. High PCV and GCV estimates were recorded for number of branches and yield per plant, whereas plant height and weight of fruit showed low estimates of PCV and GCV. Plant height, number of branches, number of fruits, weight of fruits and yield per plant registered high heritability. High genetic advance as per cent of mean was observed for number of branches, number of fruits and yield per plant.

Higher genotypic coefficient of variation was recorded for yield per plant in 40 F_1 hybrids obtained from a line x tester crossing programme. The characters *viz.,* number of branches per plant, number of pods per plant and total pod yield per plant had higher genotypic as well as phenotypic coefficients of variation. Heritability was very high for all the characters except days to first flower appearance and girth of pod. High genetic advance along with high heritability were recorded for plant height, number of pods and total pod yield per plant (Panda and Singh, 1997).

Following studies with 48 lines of okra, Dhall *et al.* (2000) reported high heritability and genetic advance as a percentage of the mean for fruit length, plant height and number of fruits per plant.

Hazra and Basu (2000) carried out the genetic variability analysis in 22 okra cultivars for different yield characters and reported high GCV for primary branches per plant. However, plant height, leaves per plant, fruit weight, fruits per plant, seeds per fruit, and fruit yield per plant recorded a moderate GCV. Plant height, fruit weight, ridges per fruit, dry weight of fruit and seeds per fruit were highly heritable while primary branches per plant, leaves per plant, days to first flower, fruit length, fruits per plant and fruit yield per plant were moderately heritable. Primary branches per plant, seeds per plant, seeds per fruit and fruit weight had high heritability and high genetic advance.

Variability analysis conducted by Gandhi *et al.* (2001) using 44 genotypes of okra for 13 different characters suggested high GCV and PCV for number of branches per plant, dry fruit yield per plant and height at first fruit set. The characters, number of branches per plant and seed yield per plant showed higher differences between GCV and PCV. Fruit length, height at first fruit set and fruit girth showed high heritability estimates.

Dhankar and Dhankar (2002a) reported in their study on different yield components in 15 advance lines of okra that all the characters showed low GCV and PCV. The fruit yield, number of fruits per plant and plant height showed high to moderate heritability. The genetic advance was medium to low for all the characters.

A study on genetic variability of 69 okra cultivars by Mulge *et al.* (2004) suggested that GCV and PCV were high for total yield per plant and number of seeds per fruit. Moderate GCV and PCV was observed for number of fruits per plant, fruit length and fruit weight, whereas fruit circumference exhibited low GCV and PCV. The characters *viz.* yield per plant, number of seeds per fruit and number of fruits per plant showed high heritability with high genetic advance, whereas fruit circumference recorded high heritability with low genetic advance.

Alam and Hossain (2006) studied the variability for yield and yield contributing characters in 50 accessions. The results revealed wide variation for weight of green pods per plant, days to first flowering and weight of individual green pods and moderate variation for length of green pod, number of green pods per plant and yield of green pods.

Jaiprakashnarayan *et al.* (2006) following variability studies with 69 okra genotypes reported high GCV and PCV for number of branches per plant, plant height at 100 DAS and internodal length. However, days to first flowering and days to 50% flowering exhibited high heritability and low genetic advance.

The genetic variability analysis by Mehta *et al.* (2006) with 22 diverse genotypes of okra for fruit yield and its components revealed that PCV were higher than GCV for all the seven traits studied. The GCV, heritability and genetic advance as percentage of mean were higher for fruit yield, fruit weight, plant height and fruit length.

Genetic variability, heritability and genetic advance for 15 characters in 19 diverse okra genotypes were studied by Singh *et al.* (2006). Estimates of PCV and GCV were high for number of branches per plant, number of fruits per plant and fruit yield per plant. The characters, number of branches per plant, fruit yield per plant, number of fruits per plant and plant height exhibited high heritability and high genetic advance.

Singh and Singh (2006) reported considerable amount of genetic variation in okra for number of branches per plant, fruit yield per plant, plant height and fruit length. The heritability estimates were high for days to first flowering. The high genetic advance and high heritability were recorded for number of branches per plant and fruit yield per plant.

Genotypic variability analysis conducted by Sood (2006) for different characters using 48 okra genotypes of diverse origin revealed that estimates of PCV and GCV were high for fruit yield per plant.

Vishalkumar *et al*. (2006) studied the genetic variability, heritability and genetic advance of fourteen characters in okra. Plant height and number of primary branches per plant showed high GCV and PCV estimates. High heritability along with high genetic advance over mean were observed for the plant height, number of primary branches per plant, internodal length, number of fruits per plant and fruit yield per plant.

Sindhumole *et al.* (2006) evaluated 101 genotypes for yield traits and observed significant variation among genotypes. High values of both PCV and GCV were noticed for protein content and fruit yield. Most of the traits including fruits per plant and fruit yield possessed high heritability. High genetic advance was noticed for protein content and fruit yield.

Singh *et al*. (2007) reported high magnitude of GCV and PCV for number of branches, plant height, number of fruits and fruit yield. PCV was higher than the corresponding GCV. The expected genetic advance as per cent of mean (genetic gain) was high for number of branches, plant height, number of fruits, fruit yield, fruit girth and fruit length. High heritability coupled with high genetic gain was observed for all the characters, except for number of fruits per plant.

Saifullah and Rabbani (2009) reported significant variations among 121 genotypes for different characters studied. The GCV and the PCV were very close in most of the characters which indicated less environmental influence on the expression of those characters. GCV and PCV were high for number of primary branches per plant, plant height, number of internodes per plant and fruit yield. The high heritability estimates along with considerable genetic advance were noticed in days to first flowering, plant height, number of primary branches per plant, number of internodes per plant, number of fruits per plant, fruit weight, number of seeds per fruits and fruit yield per plant.

Akotkar *et al.* (2010) evaluating on 50 okra genotypes for 11 characters reported wide range of variation for fruit length, fruit diameter, weight per fruit, plant height, number of nodes on main stem and fruit yield per plant. The GCV and PCV were high for number of fruiting nodes, fruit yield per plant and low for number of ridges per fruit, fruit diameter, fruit length and number of primary branches per plant. The estimates of heritability in broad sense were high for number of ridges per fruit followed by plant height and number of fruiting nodes. High genetic advance was observed for number of fruiting nodes followed by fruit yield per plant, plant height, internodal distance and number of fruits per plant; and moderate for all the remaining characters except number of primary branches.

Jindal *et al.* (2010) reported high estimates of heritability coupled with high genetic advance for number of branches per plant and yield per plant indicating presence of additive gene effects which implied the effectiveness of selection for these traits. Presence of high heritability coupled with low genetic advance for fruit weight, plant height, internodal length, number of fruits per plant and fruit length suggested that straight selection has limited scope for further improving these traits

Prakash and Pitchaimuthu (2010) evaluated genetic variability in 44 genotypes of okra for 15 characters. The genotypic variance was high for yield per plant and plant height.

Adiger *et al.* (2011) studied 163 genotypes including 43 parents and 120 crosses of okra to determine the genetic variability, PCV, GCV, heritability and genetic advance. The values of PCV were higher than that of GCV values for all the ten characters studied indicating influence of environmental effects in the expression of these characters. The GCV, heritability and genetic advance as percentage of mean were higher for plant height, fruit yield per plant, fruit weight and days to 50 per cent flowering which might be attributed to additive gene action.

Genetic variability analysis involving 100 genotypes of okra by Reddy *et al.* (2012) revealed high magnitude of genetic variability for yield and associated traits. PCV was higher than the corresponding GCV. High heritability coupled with high genetic advance revealed that significant improvement is possible through selection for all characters studied.

The studies conducted by Reddy *et al.* (2012) on 100 germplasm lines of okra revealed lowest PCV for fruit and shoot borer infestation on fruits (8.96 %) whereas, GCV was of low magnitude for fruit and shoot borer infestation on fruits (6.89 %) and fruit and shoot borer infestation on shoots (9.02 %). Moderate magnitude of heritability (30-60 %) was noticed for fruit and shoots borer infestation on fruits (59.00 %) and fruit and shoot borer infestation on shoots (55.00 %). The estimates of genetic advance as per cent of mean was moderate for fruit and shoot borer infestation on fruits (10.90 %) and fruit and shoot borer infestation on shoots (13.82 %).

2.2 CORRELATION

Yield is a complex character controlled by polygenes and highly influenced by environment. Selection merely based on yield alone is not effective. Hence in breeding efforts to enhance yield, an understanding of the relationships among different characters is inevitable. Knowledge on the contribution of different characters to yield would be highly important for formulating a selection programme. Correlation studies provide better understanding of yield components, which helps the plant breeder during selection (Johnson *et al.* 1955).

The correlation study in six varieties of okra conducted by Korla and Rastogi (1978) revealed significant positive correlation of yield per plant with fruits per plant, whereas, association with other characters was non-significant.

Singh and Singh (1978) reported that yield per plant was positively and significantly correlated with number of fruits per plant, number of branches per plant and plant height at genotypic level.

Yield per plant had significant positive correlation with number of fruits per plant at both phenotypic and genotypic level, whereas the correlation between yield and days to flowering was negative (Murthy and Bavaji, 1980).

Maksoud, *et al.* (1984) reported positive correlation of yield with plant height, fruit weight and fruit length. Late flowering was positively associated with fruits per plant and fruit size.

Significant positive genotypic correlation of yield with pods per plant, pod weight, pod length, 10-seed weight, plant height and nodes per plant was reported by Mishra and Singh (1985).

Studies by Nair and Sheela (1985) revealed significant positive correlation of yield with number of pods per plant, pod girth, pod weight and number of branches per plant.

Palve *et al.* (1985) reported significant positive correlation of yield with number of fruits. Plant height exhibited strong positive correlation with number of internodes.

Correlation studies on seven characters in okra conducted by Reddy *et al.* (1985) revealed that fruit yield per plant was positively and significantly correlated with plant height, number of branches, days to flower, fruit length, fruit width and fruits per plant. Further, all these traits showed significant positive correlation among themselves.

Yadav (1985) observed high significant positive association of yield per plant with length of pods, number of pods per plant and height of plant; whereas yield per plant was not associated with number of seeds per pod. Yield was found to be associated with days to 50 per cent flowering and number of nodes for first pod appearance. Kale *et al.* (1989) also reported positive correlation of yield with plant height and number of fruits per plant.

There are several reports of significant positive correlation of yield with number of fruits per plant and fruit weight (Balakrishnan and Balakrishan, 1990; Mishra *et al*. 1990)

The pod yield per plant had significant positive correlation with number of pods per plant, plant height and height at first flowering node. Pod yield per plant had significant negative correlation with days to 50 per cent flowering and days to first flowering (Vijay and Manohar, 1990).

Jeyapandi and Balakrishnan (1990) and Patel and Dalal (1994) reported positive correlation of yield per plant with number of fruits per plant, plant height, fruit length, fruit girth, and fruit weight. Correlation studies by Dash and Mishra (1995) also suggested positive correlation of yield per plant with fruit characters *viz.,* length, girth and weight.

Several reports indicate positive correlation of yield per plant with plant height (Gondane *et al.* 1995; Sood *et al.* 1995; Yadav, 1996; Rao, 1996).

Deo *et al.* (1996) observed that plant height, 100 - seed weight, number of seeds and length of pod had significant positive correlation among them.

Correlation analysis in 48 lines of okra was conducted by Dhall *et al.* (2000). Yield per plant, fruit weight, fruit length, number of fruits per plant and plant height showed significant positive correlation with yield per plant.

The correlation analysis of yield and yield attributes in 15 lines of okra by Dhankar and Dhankar (2002b) revealed positive association of yield with number of fruits, number of branches per plant, first fruit node on the stem and number of days to 50% flowering. Plant height and number of days to 50% flowering had negative association with yield. The number of fruits per plant had positive relationship with number of days to 50% flowering, first fruiting node on the stem and number of branches per plant

Jaiprakashnarayan and Mulge (2004) reported inverse relationship between growth and earliness, but strong association between growth and yield characters. Total yield per plant was positively and significantly correlated with number of fruits per plant, average fruit weight, number of nodes on main stem, fruit length, plant height at 60 and 100 DAS and number of leaves at 45 and 100 DAS, but negatively correlated with number of locules per fruit, number of nodes at first flowering and first fruiting.

Patro and Sankar (2006) observed that yield per plant had significant positive correlation with number of branches per plant and fruit weight. The estimates of genotypic correlation coefficient were higher than phenotypic correlation coefficient, indicating the inherent correlation among characters.

Sindhumole *et al.* (2006) indicated higher genotypic correlation coefficient than phenotypic correlation coefficient for most of the characters studied. The fruit yield displayed positive genotypic association with fruits per plant, fruit weight, fruit length, fruit girth and plant duration and negative correlation with days to first flowering.

Singh *et al.* (2006) revealed, fruit yield per plant was positively and significantly correlated with fruit length, fruit diameter, fruit weight and number of fruits per plant. Mehta *et al.* (2006) also reported significant positive correlation of fruit yield with fruit length and fruit weight.

Alam and Hossain (2008) observed that yield of green pods was positively correlated with number of nodes per plant and negatively correlated with number of branches per plant.

Ramya and Senthilkumar (2009) reported significant positive association of yield per plant with number of pods per plant and plant height.

Guddadamath *et al.* (2011) reported significant positive correlation of yield per plant with fruit weight, number of fruits per plant, 100 seed weight and number of branches per plant.

Adiger *et al.* (2011) reported significant positive correlation of fruit yield with plant height, number of branches per plant, inter-nodal length, fruit length, fruit weight and number of fruits per plant at both genotypic and phenotypic levels.

2.3 RESISTANCE TO SHOOT AND FRUIT BORER DAMAGE

Shoot and fruit borer, *Earias Vittella* Fab. (Noctuidae: Lepidoptera) is a serious pest of okra (Plates 1 and 2). The moth lay eggs on the tender parts of the plant. Eggs hatch in 3 to 4 days. The newly hatched larva bores into the terminal shoot or into fruit. Feeding on the internal contents it becomes full-fed in less than two weeks. The full-grown larva is 1.9 cm long and is brownish with white median longitudinal streak dorsally and pale yellow or green ventrally. Pupation takes place on plants in a dirty white boat shaped cocoon of tough silk for about a week. The damaged shoots droop, wither and dry up. The infested fruits present a deformed appearance and show holes on them plugged with excreta (Nair, 1999).

Srinivasan and Narayanaswamy (1961) screened 18 okra accessions for their susceptibility to okra shoot and fruit borer, of which four varieties displayed low infestation by shoot and fruit borer while the others were susceptible to varying degree. Similarly, Mote (1982) reported varieties *viz.* AE-67, wonderful pink, AE-22,

Plate 1. Adult moth of *Earias vittella*

Plate 2. Different larval instars of *E. vittella*

AE-57 and AE-52 to be comparatively resistant following varietal screening for incidence to the pest.

Gupta and Yadav (1978) evaluated 60 accessions for borer resistance and found nine were moderately resistant to borer infestation.

Raut and Sonone (1979) evaluated two wild species and 25 cultivars for resistance to fruit borer. Of the 25 cultivars tested only AE-71 proved to be fairly tolerant to pest. The wild species, *Abelmoschus manihot* and *Hibiscus tetraphyllus* were highly resistant to shoot infestation but fruit infestation was high. Twenty nine varieties and 7 F_1 were screened for resistance to shoot and fruit borer by Teli and Dalaya (1981). They found AE-79, AE-52, Sel-1-1 x AE-79 and AE-69 to be promising and less susceptible to the attack of shoot and fruit borer. After screening okra germplasm, Mote (1982) identified varieties that support lesser egg laying and larval entry into fruits and consequent low fruit borer infestation in the field.

Okra germplasm screening for shoot and fruit borer resistance performed by various workers during the eighties revealed wide variation among the genotypes and led to the identification of resistant ones (Kashyap and Verma, 1983, Singh *et al.* 1986 and Sharma and Dhankar, 1989). But resistance screening done by Madhav and Dumbre (1985) failed to identify any variety with resistance to the pest.

Bhalla *et al.* (1990) evaluated one thousand okra germplasm lines for their resistance to *Earias spp*. and reported that most of the lines were susceptible and only 50 were moderately resistant; none was completely resistant. Screening programme undertaken by Sharma *et al.* (1993) and Raj *et al.* (1993) resulted in the identification of promising genotypes with low fruit borer infestation.

Khambete and Desai (1996) screened 26 okra (*Abelmoschus esculentus*) cultivars for resistance to shoot and fruit borer (*Earias vittella*) in naturally-infested fields and found that variety wonderful Pink was tolerant.

Patil *et al.* (1996) reported zero infestation by fruit borer in 10 genotypes out of 171 genotype screened and opined that these genotypes could be used as resistance source in the development of pod borer resistant high yielding varieties. They identified the genotype PI 482025 as a high yielding one with low pest infestation.

Varietal variation in shoot and fruit damage by the pest was also reported by various workers following field trials (Shukla, *et al.* 1997; Srinivasa and Sugeetha, 2001 and Jalgaonkar *et al.* 2002).

Pandey *et al.* (2002) reported DVR-2 to be least susceptible to fruit borer among the genotypes evaluated in a screening trial. Following a screening programme for shoot and fruit borer resisitance Naresh, *et al*. (2003) found that the varieties suffering low shoot damage and fruit damage were different.

Singh, *et al.* (2005) evaluated twenty okra germplasm lines for resistance to the pest and found that none was free from infestation. Damage levels varied from 21.33 to 43.99% in case of shoots and 21.0 to 51.3% in case of fruits. Based on overall assessment, the germplasm lines *viz.,* KS-410, A4 and NDO-10 were identified as those that suffer low shoot damage as well as fruit damage.

Mondal *et al.* (2006) identified two cultivars D-1-87-5 and D-1-87-16 with low shoot and fruit borer infestation following a screening programme described them as resistant.

Thirty seven new single cross hybrids and 56 varieties were screened for okra fruit borer resistance by Koujalagi *et al.* (2009). None of the hybrids and varieties of okra was immune to the borer attack. The mean fruit borer damage among 37 okra hybrids varied from 4.93% in Saloni to 81.17% in NBH-180. The mean fruit borer damage among 56 okra varieties varied from 3.50%, in the entry number 105 to 83.28% in AOL-03-1. In laboratory, hybrid Saloni confirmed its field reaction as resistant as the moths laid fewer eggs and it was the least preferred by larvae. Similarly, entry number 105 was resistant because it was non-preferred for oviposition. It showed susceptibility to larvae. Pusa Sawani also showed considerable degree of resistance with non-preference to oviposition and larval feeding.

Sharma and Jat (2009) screened 10 new okra cultivars for resistance to shoot and fruit borer, *Earias* spp. None of the cultivars was found to be completely free from the infestation of *Earias* spp. both on shoots as well as fruits. Arka Anamika and Varsha Uphar were categorized as less susceptible having shoot infestations below 15.3% while Malav-31 and Parbhani Kranti were categorized as highly susceptible having more than 25.1% infestation. On the basis of percentage infestation on fruits, Arka Anamika and Varsha Uphar were categorized as less susceptible having below 28.8 and 28.7% infestation on number and weight basis, respectively. Nidhi-98, Malav-31 and Parbhani Kranti were categorized as highly susceptible having more than 40.0 and 40.0% infestation on number and weight basis, respectively. Plant height, fruit length, diameter and colour of the cultivars had no significant effect on the infestation of *Earias* spp.

MATERIAL AND METHODS

3. MATERIAL AND METHODS

The present study was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 2011-2012. This study aimed at the evaluation of okra genotypes for shoot and fruit borer resistance and yield to identify high yielding shoot and fruit borer resistant genotypes. The study utilized the data generated from a field experiment for evaluation of okra genotypes for shoot and fruit borer resistance and yield and a laboratory experiment to get insight into the feeding preferences of the insect.

The details of experiments conducted and the statistical analysis carried out are as follows.

3.1 EVALUATION FOR YIELD AND RESISTANCE TO SHOOT AND FRUIT BORER

A field experiment (Plate 3) was conducted with the objective of evaluating okra germplasm for yield and resistance to shoot and fruit borer.

3.1.1 Materials

The material for the study comprised of 31 genotypes of okra collected from different sources. Test entries are designated by accession numbers T_1 to T_{31}. The identity of test entries are given in Table 1 and Plate 4. shows the fruits of the 31 accessions.

Plate 3. A view of the experimental field

Table 1. Okra accessions used in the study

Acc No.	Genotype	Source
T_1	IC 7119	NBPGR, New Delhi
T_2	Hosalli local	Koratagere, Tumkur, Karnataka
T_3	HRB-9-2	University of Agricultural Sciences, Bengaluru
T_4	AE-201	College of Horticulture, Vellanikkara, Thrissur
T_5	Khalaghatagi local	Khalaghatagi, Dharwad, Karnataka
T_6	Thirumala local	Thirumala, Thiruvananthapuram
T_7	Poovam local	Panniyar
T_8	Kalliyoor local	Kalliayor, Thiruvananthapuram
T_9	Nedumangad local	Nedumangad, Thiruvananthapuram
T_{10}	Kattakkada local	Kattakada, Thiruvananthapuram
T_{11}	AE-102	College of Horticulture, Vellanikkara, Thrissur
T_{12}	Halu Bhendi	Krishi Vigyan Kendra , Brammavara, Karnataka
T_{13}	AE-116	College of Horticulture, Vellanikkara, Thrissur
T_{14}	Kunnapuzha local	Kunnapuzha, Thiruvananthapuram
T_{15}	Mallapalli local	Kottayam
T_{16}	Tirur local	Malappuram
T_{17}	Vadakkumcheri local	Palakkad
T_{18}	IC 140910	NBPGR, New Delhi

Continued…

T_{19}	Mandya local 1	Mandya, Karnataka
T_{20}	PHS-9394	University of Agricultural Sciences, Bengaluru
T_{21}	Mandya Local 2	Mandya, Karnataka
T_{22}	Belagavi local 1	Belagavi, Karnataka
T_{23}	Mandya local 3	Mandya, Karnataka
T_{24}	Mandya local 4	Mandya, Karnataka
T_{25}	Belagavi local 2	Belagavi, Karnataka
T_{26}	Belagavi local 3	Belagavi, Karnataka
T_{27}	Punjab Phalgani	Punjab Agricultural University, Ludhiana
T_{28}	Arka Abhay	IIHR, Hasaraghatta, Karnataka
T_{29}	Arka Abhay	IIHR, Hasaraghatta, Karnataka
T_{30}	Varsha Upahar	CCS Haryana Agricultural University, Hissar
T_{31}	Vellayani local	Vellayani, Thiruvananthapuram

Plate 4. Fruits of the 31 accessions

3.1.2 Methods

3.1.2.1 Layout and conduct of the experiment

The test entries were evaluated in a field experiment in randomized block design with three replications during April 2011 to August 2011. The entire field was divided into three blocks of thirty one plots each and treatments were allotted to plots in each block at random. Plot size was 3.6 m^2 and the spacing was 60 x 30 cm. The crop was managed as per Package of Practices – Recommendations (KAU, 2007) of Kerala Agricultural University. However the application of plant protection chemicals was avoided considering its possible adverse effect on target pest population build up in the experimental field.

3.1.2.2 Biometric observations

a. Days to 50 per cent flowering

Number of days taken from sowing to the day at which 50 per cent of the plants in each plot attained flowering.

The observations on the following characters were recorded from five randomly selected plants in each plot. Statistical analysis was done with mean values worked out thereafter.

b. Leaf axil bearing first fruit

The number of the leaf axil from which the first fruit was produced was recorded.

c. Number of primary branches

Number of branches arising from the main stem was recorded at final harvest.

d. Plant height (cm)

Height of the plant was measured from the ground level to the tip of main stem at final harvest.

e. Duration (days)

The number of days taken from sowing to final harvest was recorded.

f. Number of fruits per plant

The total number of fruits harvested from each observational plant was counted and recorded.

g. Yield per plant (g)

The weight of fruits from observational plants at each harvest was taken and added to get total yield and average worked out.

h. Fruit characters

Fruit weight (g), fruit length (cm) and fruit girth (cm) were recorded from 10 randomly selected fruits at vegetable maturity stage from the observational plants in each plot and mean value for each character worked out.

3.1.2.3 Shoot and fruit borer damage parameters

Shoot and fruit borer infestation under natural field conditions were evaluated based on the following damage parameters.

a. Shoot infestation percentage

Ten plants were selected from each plot at random and plants with infested shoots were counted and percentage worked.

b. Fruit infestation percentage

A random sample of 50 fruits from each plot were observed and infested fruits counted and percentage of infestation was calculated.

c. Number of larvae per 25 fruits

Twenty five fruits were collected at random from each plot and brought to the laboratory. Each fruit was dissected and the number of larvae were counted and recorded.

3.1.2.4 Classification of accessions based on fruit colour and hairiness

a. Fruit colour

Based on fruit colour the accessions were classified into five categories *viz.*, green, dark green, yellowish green, light green and green with purple blend.

b. Hairiness of fruit

Based on visual assessment of fruit hairiness, accessions were grouped into three categories *viz*., sparsely hairy, hairy and densely hairy.

3.1.2.5 Statistical analysis

The data collected from the field experiments were subjected to following statistical analysis.

3.1.2.6 Analysis of variance (ANOVA)

Analysis of variance (Panse and Sukhatme, 1985) of the data collected from the field experiment was done to test the significance of differences among genotypes with respect to the characters and to estimate the variance components (Table 2).

Table 2. ANOVA for 13 characters in 31 okra accessions

Sources of variation	Degrees of freedom	Mean square	F
Replication	(r-l)	MSR	MSR/MSE
Treatment	(t-l)	MST	MST/MSE
Error	(r-1) (t-l)	MSE	
Total	(rt-1)		

Where, r = number of replications, t = number of treatments, MSR = Replication mean square, MST = Treatment mean square, MSE = Error mean square

Critical difference (CD) = $t_{\alpha} \sqrt{\frac{2MSE}{r}}$

Where , t_{α} is the student's t table value at error degrees of freedom and α is the level of significance (0.05)

3*.1.2.7 Estimation of genetic parameters*

a. Genetic components of variance**.**

For each character, the phenotype and genotypic components of variance were estimated by equating the expected values of mean squares (MS) to the respective variance components (Jain, 1982). Based on this, the following variance components were estimated.

i. Genotypic variance (V_G)

$$V_G = \frac{MST - MSE}{r}$$

ii. Environmental variance (V_E)

$$V_E = MSE$$

iii. Phenotypic variance (V_P)

$$V_P = V_G + V_E$$

b. Coefficients of variation.

Genotypic and phenotypic coefficients of variation were worked out using the estimates of V_G and V_P expressed in percentage (Burton, 1952) for each trait.

i. Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sqrt{V_p}}{\overline{X}} \times 100$$

ii. Genotypic coefficient of variation (GCV)

$$GCV = \frac{\sqrt{V_G}}{\overline{X}} \times 100$$

$\overline{X}$ is the mean of each character estimated over all the treatments

The PCV and GCV were classified as, low (<10%), moderate (10-20%) and high (>20%)

c. Heritability

For each trait, heritability (broad sense) was calculated as the ratio of genotypic variance to phenotypic variance and expressed as percentage (Lush, 1937).

Heritability (H^2) = $\frac{V_G}{V_P} \times 100$

Heritability was categorized as low (< 30%), moderate (31-60%) and high (>60%) as suggested by Robinson *et al.,* (1949).

d. Genetic advance

Genetic advance which is the measure of genetic gain under selection depends upon standardized selection differential, heritability and phenotypic standard deviation (Allard, 1960).

Genetic advance (GA) = $k.H^2 \sqrt{V_P}$

Where k is the standardised selection differential (2.06 at 5% selection)

GA as percentage of mean = $k.H^2 \frac{\sqrt{V_P}}{\overline{X}} \times 100$

Genetic advance as percentage of mean was categorized as low (< 10%), moderate (11-20%) and high (>20%) as suggested by Robinson *et al.,* (1949).

3.1.2.8 Correlation analysis

Phenotypic, genotypic and environmental correlation coefficients were calculated for pairs of traits using the respective variances and co-variances.

Phenotypic correlation coefficients, $r_{PXY} = \frac{COV_P(X,Y)}{\sqrt{V_P(X).V_P(Y)}}$

Genotypic correlation coefficient, $r_{GXY} = \frac{COV_G(X,Y)}{\sqrt{V_G(X).V_G(Y)}}$

Environmental correlation coefficient, $r_{EXY} = \frac{COV_E(X,Y)}{\sqrt{V_E(X).V_E(Y)}}$

Where, COV_P (x, y), COV_G (x, y) and COV_E (x, y) denote the phenotypic, genotypic and error co-variances between the two traits X and Y respectively.

V_P (x), V_G (x), and V_E (x) respectively are the phenotypic, genotypic and error variance for trait X and V_P (y), V_G (y), and V_E (y) indicate the phenotypic, genotypic and error variance for the trait Y.

3.2 ASSESSMENT OF FEEDING PREFERENCES

Laboratory experiment was conducted to assess the feeding preferences of shoot and fruit borer.

3.2.1 Materials

The material for the study comprised of one week old healthy fruits of each of the 31 genotypes and a collection of third instar larvae of the shoot and fruit borer, *Earias vittella* apart from two circular trays of 90 cm diameter, muslin cloth and petri dishes.

3.2.2 Methods

3.2.2.1 Layout and conduct of the experiment

The experiment was conducted in completely randomized design with two replications. Three one week old healthy fruits of each of the genotypes were randomly placed at equal distances along the periphery of each circular tray and carefully labeled. One day starved 100 third instar larvae were introduced at the centre of each tray in a petri dish (Plates 5). The trays were covered with muslin cloth and tightly tied. In third day, the number of infested fruits and number of larvae in the fruits of each variety was separately counted. Feeding preferences was inferred on the basis of severity of fruit infestation.

3.2.2.2 Collection of data

a. Number of infested fruits

Number of infested fruits in each genotype in each replication was recorded.

b. Number of larvae in fruits

Number of larvae in the fruits of each of the genotypes was recorded.

3.2.2.3 Statistical analysis

The data collected for the laboratory experiments were subjected to statistical analysis.

Plate 5. Third instar larvae of E. vittella

3.2.2.4 Analysis of variance (ANOVA)

Analysis of variance (Panse and Sukhatme, 1985) of the data collected from the laboratory experiment was done to test the significance of differences among genotypes with respect to damage parameters (Table 3).

Table 3. ANOVA for laboratory experiment on feeding preferences

Sources of variation	Degrees of freedom	Mean square	F
Treatment	(t-l)	MST	MST/MSE
Error	t(r-1)	MSE	
Total	(rt-1)		

Where, r = number of replications, t = number of treatments, MST = Treatment mean square, MSE = Error variance

Critical difference (CD) = $t_{\alpha}\sqrt{\frac{2MSE}{r}}$

Where, t_{α} is the student's t table value at error degrees of freedom and α is the level of significance (0.05).

RESULTS

4. RESULTS

Thirty one genotypes of okra were collected and evaluated for yield and resistance to shoot and fruit borer (*Earias vittella* Fab.) at the College of Agriculture, Vellayani during the period 2011-2012. The data collected from the field and laboratory experiments were subjected to statistical analysis. The results of the study are presented hereunder.

4.1 EVALUATION OF OKRA GENOTYPES FOR YIELD AND RESISTANCE TO SHOOT AND FRUIT BORER

The analysis of variance (Table 4) revealed highly significant differences among the varieties for all the characters studied. The mean values of each of the 31 okra genotypes for the 10 characters of yield traits studied are presented in Table 5.

4.1.1 Yield traits

Significant differences were noticed among the entries for days to 50% flowering. The mean values ranged from 43.33 to 59.33. T_{27} was the earliest flowering type. T_{17}, T_{24}, T_{25}, T_{28}, and T_{30} were on par with T_{27} with respect to the days to 50 per cent flowering. T_8 took the maximum time for flowering followed by T_4.

The genotypes differed significantly for leaf axil bearing first fruit. T_3 had the lowest value of 3.80 as against T_{16} with the highest value of 6.60 for leaf axil bearing first fruit. None of the varieties were on par with either T_3 or T_{16} for this character.

Table 4. Analysis of variance in okra genotypes for fruit yield and its attributes.

Characters	Mean sum of square		
	Replication	Genotypes	Error
Days to 50% flowering	0.20	71.64**	0.97
Leaf axil bearing first fruit	0.05	1.41**	0.03
Number of primary branches	0.04	1.75**	0.02
Plant height (cm)	0.80	1173.11**	5.32
Duration (days)	1.46	747.95**	1.03
Number of fruits per plant	0.05	16.57**	0.13
Fruit weight (g)	0.22	49.11**	0.19
Fruit length (cm)	0.05	7.24**	0.04
Fruit girth (cm)	0.02	0.52**	0.03
Yield per plant(g)	24.45	7353.57**	58.89
Shoot infestation (%)	12.19	147.49**	19.96
Fruit infestation (%)	4.48	121.83**	1.68
Number of larvae per 25 fruits	2.85	41.87**	1.41

** Significant at 1% level

Table 5. Mean performance of okra genotypes.

Acc No.	1	2	3	4	5	6	7	8	9	10
T1	55.66	5.53	2.53	85.14	88.00	12.00	18.51	12.36	6.38	218.82
T2	56.33	4.53	3.60	84.35	80.66	9.73	25.57	13.46	7.08	239.79
T3	47.00	3.80	1.60	67.46	85.13	12.86	21.49	14.20	6.84	272.21
T4	58.00	5.80	3.20	97.38	94.40	11.33	15.12	9.22	7.10	169.31
T5	56.66	5.26	2.20	112.40	99.60	6.60	15.76	11.64	6.20	103.18
T6	48.66	5.66	2.60	117.38	92.73	5.00	30.35	16.07	6.21	149.34
T7	56.33	6.26	1.46	70.33	86.86	5.80	18.24	12.84	6.30	104.46
T8	59.33	5.33	0.93	90.52	80.66	11.20	19.50	13.43	6.08	216.29
T9	54.00	5.66	2.06	83.06	81.80	10.60	15.42	14.68	6.21	160.21
T10	54.66	6.13	3.26	120.40	82.73	13.00	21.06	13.54	6.98	271.83
T11	53.33	4.93	1.13	88.88	92.33	10.53	15.59	13.62	6.28	161.18
T12	54.33	4.86	1.00	102.15	100.33	10.60	17.71	13.46	5.91	186.38
T13	49.00	5.33	2.06	108.05	87.26	11.86	19.46	13.62	6.58	229.78
T14	45.66	6.26	2.20	126.70	96.66	7.66	26.69	12.53	5.60	203.27
T15	49.00	5.86	0.73	97.40	81.40	13.53	21.41	13.40	6.63	289.39
T16	49.00	6.60	2.33	90.87	79.93	12.20	17.78	13.24	6.23	213.74
T17	44.66	5.00	1.46	92.70	82.93	11.33	20.32	11.02	6.74	228.70
T18	46.00	5.20	3.06	75.00	78.53	10.73	15.42	12.20	5.33	162.74
T19	47.33	4.60	3.13	127.96	89.60	15.00	16.12	13.22	6.33	239.49
T20	54.00	4.13	1.93	128.25	120.53	9.26	17.01	11.26	6.12	155.87
T21	45.00	5.33	2.20	132.98	130.26	12.06	23.05	12.98	6.57	275.54
T22	49.33	4.46	1.00	95.48	96.00	11.20	22.12	13.34	6.81	245.18
T23	54.00	4.80	1.60	133.43	125.60	8.33	18.73	11.90	6.18	154.56
T24	44.00	5.06	2.20	127.80	127.80	9.93	22.19	14.39	6.52	219.51
T25	44.33	5.53	1.33	87.86	89.60	12.80	18.08	13.88	6.54	229.99
T26	47.00	5.26	1.80	125.90	124.00	10.33	14.91	11.30	6.10	152.83
T27	43.33	4.60	2.13	85.36	87.33	12.86	21.32	12.55	6.75	273.26
T28	44.33	4.20	2.26	76.30	78.66	10.53	17.50	13.58	6.55	183.60
T29	46.33	4.80	1.20	102.35	99.93	6.53	28.36	13.31	6.69	174.91
T30	44.33	5.00	1.40	117.50	113.93	9.13	25.66	18.05	5.81	232.48
T31	49.66	6.26	1.20	102.13	103.20	11.66	19.97	13.24	6.84	230.88
CD(0.05)	1.60	0.30	0.28	3.76	1.66	0.59	0.72	0.36	0.32	12.53
Mean	50.01	5.22	1.96	101.72	95.43	10.52	20.01	13.14	6.40	204.79

1. Days to 50% flowering
2. Leaf axil bearing first fruit
3. Number of primary branches
4. Plant height
5. Duration
6. Number of fruits per plant
7. Fruit weight
8. Fruit length
9. Fruit girth
10. Yield per plant

The accession T_2 had the maximum number of primary branches (3.60) and all other genotypes produced significantly lesser number of primary branches. The genotype T_{15} had the least number of primary branches (0.73). Other genotypes with fewer number of primary branches included T_8, T_{15}, T_{12} and T_{22}.

Wide variation in plant height was noticed among varieties ranging from 67.46 cm (T_3) to 133.43 cm (T_{23}). T_{21} was on par with T_{23}, while T_7 was on par with T_3.

There was wide variation in duration among the genotypes studied with the values ranging from 78.53 to 130.26 days recorded by T_{18} and T_{21} respectively. T_{16} and T_{28} were found to be on par with T_{18}.

The number of fruits per plant ranged from 5.00 (T_6) to 15.00 (T_{19}). T_{19} was significantly superior to all other genotypes in the number of fruits per plant.

Fruit characters *viz.,* fruit weight, fruit length and fruit girth differed significantly among the genotypes. Fruit weight ranged from 14.91g (T_{26}) to 30.35g (T_6). None of the other genotypes was on par with T_6 in fruit weight. Genotypes with low fruit weight comparable to T_{26} included T_4, T_9, T_{11} and T_{18}. Commendable variation in fruit length ranging from 9.22 cm (T_4) to 18.05 cm (T_{30}) could be observed among genotypes. No other variety had fruit length comparable to T_{30}. Appreciable variation in fruit girth was observed among genotypes. Highest fruit girth was recorded by T_4 (7.10 cm) followed by T_2, T_3, T_{10}, T_{31} and T_{22} which were on par with it. Lowest mean value 5.33 cm was for T_{18} and T_{14} was on par with it.

Yield per plant ranged from 103.18 g (T_5) to 289.39 g (T_{15}). T_{15} is significantly superior to other genotypes in yield per plant. T_7 was a low yielding accession with yield per plant similar to T_5, the lowest yielder.

4.1.2 Shoot and fruit borer damage parameters

The major feeding sites of *E. vittella* are shoots and fruits. Screening of genotypes based on the extent of damage of shoots and fruits as well as the number of larvae in fruits was attempted in the present study. The young larvae bore and feed inside the shoots and fruits. The shoots wilt and dry (Plate 6). The damaged plants develop branches which bear smaller fruits. During the reproductive stage, the larvae feed on the flowers and bore inside the fruits. The larva feeds and completes its larval development inside the stems and fruits. Damaged plant parts can easily be detected by the fresh frass and bore holes on the fruits. Early damage on fruits also causes deformed fruits (Plate 7). Presence of larva inside a fruit, longitudinally cut is shown in Plate 8 and Plate 9 shows the comparison between healthy fruits and infested fruits

Shoot and fruit borer damage assessed by all the three damage criteria, *viz.,* percentage shoot infestation, percentage fruit infestation and larval count in 25 fruits differed significantly among the accessions and mean values with respect to different damage parameters are presented in Table 6.

The percentage of *E. vittella* infestation on shoots ranged from 3.33 (T_{22} and T_{23}) to 33.33 in (T_{16} and T_{24}). Four genotypes *viz.,* (T_4, T_7, T_8 and T_{27}) were on par with T_{22} and T_{23}. Seven genotypes (T_1, T_2, T_5, T_{11}, T_{13}, T_{20} and T_{25}) were on par with T_{16} and T_{24} . The general mean value for shoot infestation was 15.59.

Plate 6. Typical damage symptom on shoot

Plate 7. Larval entry holes on infested fruits plugged with excreta

Plate 8. Larvae feeding inside the fruit

Plate 9. Healthy fruits and infested fruits

Table 6. Shoot and fruit damage measurements

Acc No.	Shoot infestation (%)	Fruit infestation (%)	Number of larvae per 25 fruits
T1	23.33 (28.78)	36 (36.86)	9.66 (9.61)
T2	23.33 (28.78)	35.33 (36.46)	9 (9.21)
T3	10 (18.43)	34.66 (36.06)	8.33 (8.81)
T4	6.66 (14.20)	32 (34.44)	5.66 (7.08)
T5	26.66 (30.99)	12 (20.22)	3 (5.02)
T6	13.33 (21.14)	35.33 (36.46)	8.66 (9.01)
T7	6.66 (14.20)	13.33 (21.32)	3.66 (5.61)
T8	6.66 (14.20)	15.33 (23.04)	1.33 (3.29)
T9	10 (18.43)	10 (18.37)	1 (3.29)
T10	10 (18.43)	29.33 (32.79)	6 (7.32)
T11	23.33 (28.78)	15.33 (22.98)	2.33 (4.42)
T12	13.33 (21.14)	34.66 (36.06)	8.66 (9.01)
T13	23.33 (28.78)	13.33 (21.40)	2.66 (4.74)
T14	16.66 (23.85)	32 (34.44)	6 (7.32)
T15	10 (18.43)	30 (33.20)	5 (6.64)
T16	33.33 (35.21)	30 (33.20)	5.66 (7.10)
T17	13.33 (21.14)	29.33 (32.77)	6.33 (7.55)
T18	10 (18.43)	30.66 (33.62)	5.66 (7.08)
T19	16.66 (23.85)	13.33 (21.37)	3.66 (5.61)

Continued…

T_{20}	26.66 (30.99)	29.33 (32.79)	6 (7.32)
T_{21}	10 (18.43)	31.33 (34.03)	6.33 (7.55)
T_{22}	3.33 (9.97)	30 (33.20)	6 (7.32)
T_{23}	3.33 (9.97)	13.33 (21.40)	3.33 (5.29)
T_{24}	33.33 (35.21)	35.33 (36.46)	8.66 (9.01)
T_{25}	30 (33.21)	36 (36.86)	8.66 (9.00)
T_{26}	20 (26.56)	34 (35.66)	9.33 (9.41)
T_{27}	6.66 (14.20)	14 (21.93)	2.33 (4.42)
T_{28}	13.33 (21.14)	34 (35.66)	8.33 (8.81)
T_{29}	10 (18.43)	35.33 (36.46)	9.66 (9.61)
T_{30}	13.33 (21.14)	31.33 (34.03)	6.33 (7.53)
T_{31}	16.66 (23.85)	30.66 (33.62)	5.66 (7.10)
CD (0.05)	7.29	2.12	0.97
Mean	15.59 (22.27)	26.98 (30.88)	5.90 (7.10)

* Values in parentheses are angular-transformed values

None of the accessions were found free of fruit infestation. Percentage of fruit infestation ranged from 10.00 (T9) to 36.00 (T1 and T25). T5 was on par with T9 and eight genotypes (T2, T3, T6, T12, T24, T26, T28 and T29) were on par with T1 and T25. T5 was on par with T9. The general mean value was found to be 26.98.

Each genotype was critically evaluated for number of larvae in twenty five fruits selected at randomly. The mean values ranged from 1.00 (T9) to 9.66 (T1 and T29). T8 was on par with T9. High larval count in fruits were observed in eight other genotypes (T2, T3, T6, T12, T24, T25, T26 and T28).

T9 is identified as an accession suffering relatively low damage irrespective of criteria employed.

Based on colour of the fruits, accessions were classified into light green, yellowish green, green, dark green and green with purple blend (Table 7).

Table 7. Classification of accessions based on fruit colour

Colour	**Accessions**
Light green	T2, T3, T4, T5, T6, T11, T12, T13, T14, T15, T17, T31
Yellowish green	T1, T7, T9, T16, T25, T27, T29
Green	T8, T10, T18, T22, T24, T26, T28
Dark green	T19, T20, T21, T23
Green with purple blend	T30

Based on visual assessment, accessions were categorized into sparsely hairy, hairy and densely hairy (Table 8).

Table 8. Classification of accessions based on hairiness of fruit wall

Visual appearance	**Accessions**
Sparsely hairy	T3, T5, T12, T17, T24, T25, T29, T31
Hairy	T1, T4, T6, T9, T11, T15, T19, T20, T21, T23, T27, T28, T30
Densely hairy	T2, T7, T8, T10, T13, T14, T16, T18, T22, T26

A pursual of the data on fruit infestation and fruit colour or hairiness does not suggest any apparent relationship of fruit damage with either fruit colour or hairiness of fruit wall.

4.1.3 Coefficients of variation

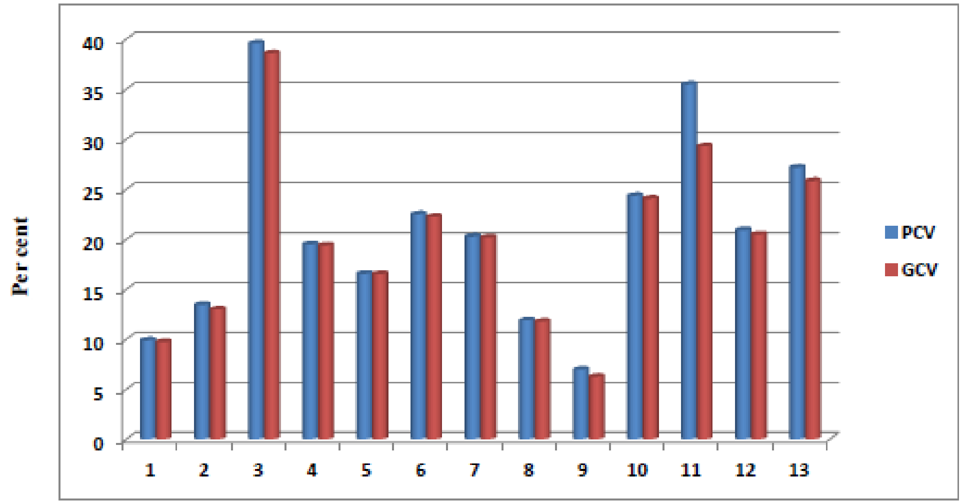
The genetic parameters *viz*., phenotypic and genotypic coefficients of variation for each character under study are presented in Table 9 and Fig 1.

High PCV were observed for several characters, the highest being for number of primary branches (39.56) followed by shoot infestation (35.48), number of larvae per 25 fruits (27.17), yield per plant (24.36), number of fruits per plant (22.51), fruit infestation (20.92) and fruit weight (20.29). Characters *viz*., leaf axil bearing first fruit (13.43), plant height (19.52), duration (16.56) and fruit length (11.89) recorded moderate estimates of PCV. Fruit girth (6.96) and days to 50% flowering (9.90) showed low magnitude of PCV values.

Among the different characters studied, the magnitude of GCV was the highest for number of primary branches (38.57). The other characters which were high in GCV values were shoot infestation (29.27), number of larvae per 25 fruits (25.84), yield per plant (24.07), fruit infestation (20.49), number of fruits per plant (22.24)and fruit weight (20.17). Moderate values of GCV were recorded for the

Table 9. Components of variance for 13 characters in okra

Sl. No.	Characters	GV	PV	GCV %	PCV %
1	Days to 50% flowering	23.55	24.52	9.70	9.90
2	Leaf axil bearing first fruit	0.46	0.49	12.96	13.43
3	Number of primary branches	0.57	0.60	38.57	39.56
4	Plant height (cm)	389.26	394.59	19.39	19.52
5	Duration (days)	248.97	250.00	16.53	16.56
6	Number of fruits per plant	5.48	5.61	22.24	22.51
7	Fruit weight (g)	16.30	16.50	20.17	20.29
8	Fruit length (cm)	2.39	2.44	11.77	11.89
9	Fruit girth (cm)	0.16	0.19	6.25	6.96
10	Yield per plant(g)	2431.56	2490.45	24.07	24.36
11	Shoot infestation (%)	42.50	62.47	29.27	35.48
12	Fruit infestation (%)	40.04	41.73	20.49	20.92
13	Number of larvae per 25 fruits (%)	53.93	59.61	25.84	27.17



1. Days to 50% flowering
2. Leaf axil bearing first fruit
3. Number of primary branches
4. Plant height
5. Duration
6. Number of fruits per plant
7. Fruit weight
8. Fruit length
9. Fruit girth
10. Yield per plant
11. Shoot infestation (%)
12. Fruit infestation (%)
13. Number of larvae per 25 fruits

Fig 1. Phenotypic and genotypic coefficients of variation for the thirteen characters in okra

characters, leaf axil bearing first fruit (12.96), plant height (19.39), duration (16.53) and fruit length (11.77). Low values of GCV were evident for fruit girth (6.25) and days to 50% flowering (9.70)

In general, phenotypic coefficient of variation was greater than genotypic coefficient of variation. The highest phenotypic and genotypic coefficients of variation were recorded for number of primary branches per plant (39.56 and 38.57, respectively) followed by shoot infestation (35.48 and 29.27, respectively). The lowest PCV and GCV were for fruit girth (6.96 and 6.25) followed by days to 50% flowering (9.90 and 9.70).

The differences between phenotypic and genotypic coefficients of variation were low for the characters *viz*., number of primary branches, yield per plant and number of fruits per plant which suggests low environmental influence in the expression of the character and better scope for selection.

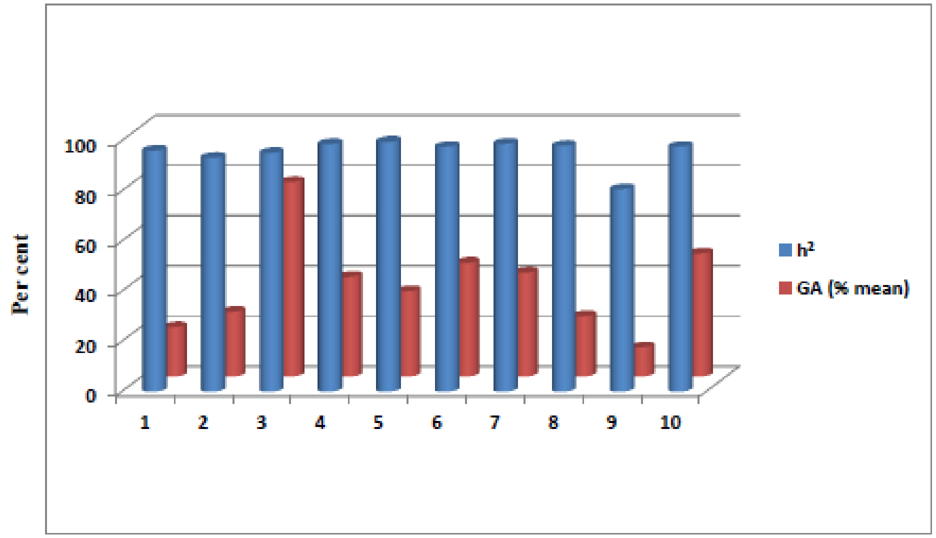
4.1.4 Heritability and Genetic Advance

The estimates of heritability and genetic advance for the ten characters studied are presented in Table 10 and Fig. 2. All the characters under study showed high heritability. The heritability in broad sense ranged from 80.64 to 99.58% and expected genetic advance over percentage of mean ranged from 11.57% to 77.49%.

The highest heritability was recorded for duration (99.58%) with an expected genetic advance of 33.98%, followed by fruit weight (98.79%) with an expected genetic advance of 41.30%. High heritability coupled with high genetic advance were also observed for number of primary branches, plant height, fruit length, yield per plant, number of fruits per plant, leaf axil bearing first fruit. The genetic advance for

Table 10. Heritability, Genetic advance and Genetic gain for the 10 characters in okra

Sl. No.	Characters	Heritability (%)	Genetic advance (at 5% selection intensity)	Genetic gain (as % of mean)
1	Days to 50% flowering	96.04	9.79	19.58
2	Leaf axil bearing first fruit	93.15	1.34	25.78
3	Number of primary branches	95.09	1.52	77.49
4	Plant height (cm)	98.64	40.36	39.68
5	Duration (days)	99.58	32.43	33.98
6	Number of fruits per plant	97.60	4.76	45.27
7	Fruit weight (g)	98.79	8.26	41.30
8	Fruit length (cm)	97.96	3.15	24.00
9	Fruit girth (cm)	80.64	0.74	11.57
10	Yield per plant(g)	97.63	100.37	49.00



1. Days to 50% flowering
2. Leaf axil bearing first fruit
3. Number of primary branches
4. Plant height
5. Duration
6. Number of fruits per plant
7. Fruit weight
8. Fruit length
9. Fruit girth
10. Yield per plant

Fig 2. Heritability and genetic advance for ten characters in okra days to 50% flowering and fruit girth was found to be moderate even though their heritability estimates were high.

4.1.5 Correlation studies

The results of the correlation studies are presented under the following sub-headings.

a. Correlation between yield and other characters
b. Correlation among yield component characters
c. Correlation among shoot and fruit borer damage parameters

a. Correlation between yield and other characters

The genotypic and phenotypic correlation coefficients of yield with other characters are presented in Table 11 and genotypic correlation of yield with other characters is illustrated in Fig 3.

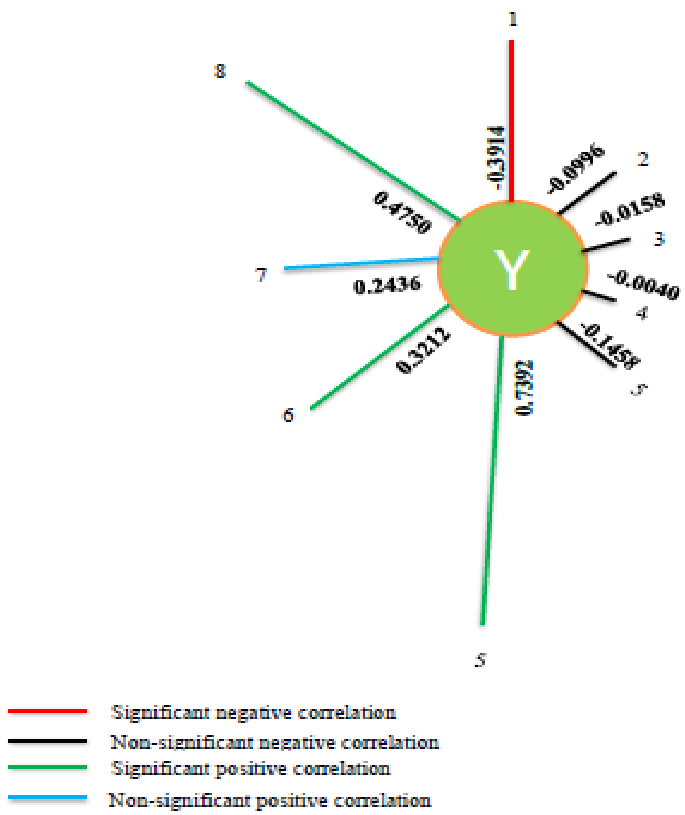
The phenotypic correlation was found to be highly significant and positive for number of fruits per plant (0.7389), fruit weight (0.3242) and fruit girth (0.4294). Leaf axil bearing first fruit, number of primary branches, plant height, duration and fruit length were not correlated with yield per plant. Days to 50% flowering (-0.3813) recorded negative phenotypic correlation.

The genotypic correlation of yield per plant with number of fruits per plant, fruit weight and fruit girth were found to be significant and positive. Number of fruits per plant had the highest positive correlation with yield per plant (0.7392) followed by fruit girth (0.4750) and fruit weight (0.3212). Days to 50% flowering was negatively associated with yield per plant (-0.3914). On the other hand the characters

Table 11. Correlation between yield and other characters

Sl. No.	Characters	Correlation coefficients	
		Genotypic	Phenotypic
1	Days to 50% flowering	-0.3914**	-0.3813**
2	Leaf axil bearing first fruit	-0.0996	-0.0909
3	Number of primary branches	-0.0158	-0.0154
4	Plant height (cm)	-0.0040	-0.0045
5	Duration (days)	-0.1458	-0.1452
6	Number of fruits per plant	0.7392**	0.7389**
7	Fruit weight (g)	0.3212**	0.3242**
8	Fruit length (cm)	0.2436	0.2431
9	Fruit girth (cm)	0.4750**	0.4294**

** Significant at 1% level



1. Days to 50% flowering
2. Leaf axil bearing first fruit
3. Number of primary branches
4. Plant height
5. Duration
6. Number of fruits per plant
7. Fruit weight
8. Fruit length
9. Fruit girth

Fig. 3. Genotypic correlation of yield with other characters

viz., leaf axil bearing first fruit, number of primary branches, plant height, duration and fruit length were not correlated with yield per plant at genotypic level.

b. Correlation among yield component characters

The phenotypic and genotypic correlation coefficients among the yield components are presented in Table 12 and 13 respectively.

Number of days to 50% flowering recorded significant negative phenotypic correlation with fruit weight (-0.3178) and fruit length (-0.2894) but it was not correlated with leaf axil bearing first fruit, number of primary branches, plant height, duration, number of fruits per plant and fruit girth. Fruit weight and fruit length recorded significant negative genotypic correlation (-0.3248 and -0.2984) respectively. Leaf axil bearing first fruit, number of primary branches, plant height, duration, number of fruits per plant and fruit girth were not correlated to days to 50% flowering at genotypic level.

Correlation analysis did not demonstrate association of leaf axil bearing first fruit or number of primary branches with any other character at phenotypic and genotypic levels.

Plant height showed significant positive correlation with duration both at phenotypic (0.7479) and genotypic (0.7521) levels. No other character is found to be correlated with plant height.

Genotypic correlation between number of fruits per plant and duration was negative and significant both at phenotypic and genotypic levels. Correlation analysis does not suggest significant association of duration with any other character.

Table 12. Phenotypic correlations among yield component characters

	X1	X2	X3	X4	X5	X6	X7	X8	X9
X1	1	0.1792	0.0998	-0.1157	-0.1580	-0.1784	-0.3178*	-0.2894*	0.0572
X2		1	0.0527	0.0618	-0.1484	-0.0851	-0.0016	-0.0332	-0.1027
X3			1	0.1025	-0.1590	0.0710	-0.0379	-0.1823	0.0944
X4				1	0.7479**	-0.1411	0.2037	-0.0146	-0.1545
X5					1	-0.2541*	0.0894	-0.0437	-0.1350
X6						1	-0.3653**	-0.0920	0.3107*
X7							1	0.5030**	0.1352
X8								1	-0.1370
X9									1

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

X1= Days to 50% flowering
X2= Leaf axil bearing first fruit
X3= Number of primary branches
X4= Plant height
X5= Duration
X6= Number of fruits per plant
X7= Fruit weight
X8= Fruit length
X9= Fruit girth

Table 13. Genotypic correlations among yield component characters

	X1	X2	X3	X4	X5	X6	X7	X8	X9
X1	1	0.1905	0.0956	-0.1182	-0.1606	-0.1824	-0.3248**	-0.2984*	0.0767
X2		1	0.0718	0.0629	-0.1534	-0.0869	-0.0027	-0.0344	-0.1209
X3			1	0.1041	-0.1659	0.0722	-0.0398	-0.1872	0.1035
X4				1	0.7521**	-0.1445	0.2075	-0.0146	-0.1849
X5					1	-0.2571*	0.0912	-0.0446	-0.1632
X6						1	-0.3698**	-0.0946	0.3498**
X7							1	0.5080**	0.1448
X8								1	-0.1635
X9									1

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

X1= Days to 50% flowering
X2= Leaf axil bearing first fruit
X3= Number of primary branches
X4= Plant height
X5= Duration
X6= Number of fruits per plant
X7= Fruit weight
X8= Fruit length
X9= Fruit girth

Correlation analysis suggested positive correlation of number of fruits per plant with fruit girth and negative correlation with fruit weight both at phenotypic and genotypic levels. Fruit weight in turn was found to be positively correlated with fruit length both at phenotypic and genotypic levels. However, correlation analysis failed to suggest any association between fruit length and fruit girth.

c. Correlation among shoot and fruit borer damage parameters

Simple (Pearson's) correlation coefficients among shoot and fruit borer damage parameters are shown in Tables 14.

The results suggested that there was no relationship between shoot infestation and other damage parameters *viz.,* between percentage fruit infestation and number of larvae in fruits.

Highly significant positive correlation between fruit infestation and number of larvae per 25 fruits (0.9190) was evident in the present investigation.

4.2 LABORATORY EXPERIMENT TO STUDY FEEDING PREFERENCE

The laboratory experiment was conducted to infer about the feeding preferences of the *E. vittella.* The experiment was conducted in CRD with two replication. In each replication, hundred third instar larvae were introduced into the centre of a circular tray in which three tender fruits each of the 31 accessions were randomly placed in a circular fashion at equal distance along the periphery of the tray (Plate 10). The data on number of infested fruits and number of larvae in the fruits were recorded in the third day. The data were subjected to statistical analysis.

Table 14. Simple (Pearson's) correlation among pest characters of okra

	Shoot infestation (%)	Fruit infestation (%)	Number of larvae per 25 fruits
Shoot infestation (%)	1	0.1894	0.2529
Fruit infestation (%)		1	0.9190**
Number of larvae per 25 fruits			1

** Significant at 1%

Plate 10. Circular tray along with larvae at the centre along with three fruits each of 31 accessions

The analysis of variance (Table 15) revealed highly significant differences among the varieties for number of fruits infested and number of larvae in fruits.

Table 15. ANOVA for laboratory experiment on feeding preferences

Characters	Mean sum of square	
	Replication	Genotypes
Number of fruits infested	1.50	0.43**
Number of larvae	4.16	0.51**

** Significant at 1% level

The mean values on the shoot and fruit damage parameters are presented in Table 16.

All the three fruits in both replications were found to be infested by the larvae in several genotypes (T_1, T_2, T_3, T_{24}, T_{25}, T_{26}, T_{28} and T_{29}). Apart from the above mentioned genotypes several others were found to have equally severe fruit infestation (T_4, T_6, T_{12}, T_{13}, T_{14}, T_{21} and T_{22}).

The genotypes T_8 and T_9 were found to have the least fruit infestation. Other genotypes with low fruit infestation included T_5, T_7, T_{10}, T_{11}, T_{15}, T_{16}, T_{17}, T_{18}, T_{19}, T_{20}, T_{23} and T_{27}.

The number of larvae in fruits also showed significant variation among the genotypes evaluated. The values ranged from 0.50 to 6.00. T_9 was the genotype with lowest larval count in fruits. Genotypes with lesser number of larvae in fruits included T_8, T_{13}, T_{16}, T_{19}, T_{23} and T_{27}. Larval count as high as 6.00 could be found in genotype T_2. Similarly, higher larval counts were observed in other genotypes *viz*., T_3, T_4, T_5 and T_6.

Table 16. Mean performance of okra genotypes for pest feeding preferences

ACC No.	Number of fruits infested	Number of larvae
T1	3	3
T2	3	6
T3	3	5
T4	2.5	5.5
T5	1	5.5
T6	2.5	5.5
T7	1	2.5
T8	0.5	1.5
T9	0.5	0.5
T10	1	3.5
T11	1	2
T12	2	4.5
T13	2	1.5
T14	2.5	2.5
T15	1.5	2
T16	1	1
T17	1.5	3
T18	1.5	3.5
T19	1	1.5
T20	1.5	3
T21	2.5	2.5
T22	2.5	3.5
T23	1	1.5
T24	3	3.5
T25	3	3.5
T26	3	3.5
T27	1	1.5
T28	3	3.5
T29	3	4.5
T30	2	2.5
T31	2	2.5
CD (0.05)	1.34	1.44
Mean	1.91	3.08

When the number of infested fruits and larval count in fruits were simultaneously considered, the genotype T_9 was found to have lowest infestation fruits and lowest number of larvae in fruits. Hence it is inferred that genotype T_9 is the accession least preferred for feeding by shoot and fruit borer larvae (Plate 11).

Plate 11. Accession suffering relatively low damage against *E. vittella*

DISCUSSION

5. DISCUSSION

Okra is mainly grown for its young immature fruits and consumed as a vegetable, raw, cooked or fried. Okra is attacked by several species of insect pests and infected by a few diseases from seedling to harvesting. Economic losses depend on the degree of damage, pest population, environmental condition, stage of crop growth and the plant part damaged by the pest. *E. vittella* at early vegetative stage damage the shoots. The plants then develop branches to compensate for the damage by borers. Unlike other crops such as eggplant, development of more branches in okra is disadvantageous. Pods from branches are few and small. Shoot and fruit borer larvae feed on flowers and bore inside the pods inflicting severe crop loss in the event of serious infestation.

Crop improvement largely depends on the magnitude of the genetic variability and the extent to which the desirable traits are heritable. Correlation analysis of yield and yield contributing characters will be useful in formulating selection programmes.

The present study was conducted to evaluate the variability for yield and yield attributing characters in 31 genotypes of okra and to screen the genotypes against shoot and fruit borer incidence under field condition as well as under laboratory condition.

The results of the experiments are discussed hereunder.

5.1 EVALUATION OF OKRA GENOTYPES FOR YIELD AND RESISTANCE TO SHOOT AND FRUIT BORER

5.1.1 Variability studies

The breeding procedure, efficiency of selection and final success are dependent on the germplasm chosen (Zelleke, 2000). The observed variability in a population is the sum total of the variation arising due to genotypic and environmental effects. Knowledge of the nature and magnitude of genetic variation contributing to gain under selection is of utmost importance (Allard, 1960). Analysis of variance helps in partitioning the total phenotypic variation into components attributable to genotype and environment thereby providing information regarding the nature and magnitude of variability of a trait.

The present study revealed significant differences among 31 genotypes of okra for all the biometric characters studied *viz*., days to 50 per cent flowering, leaf axil bearing first fruit, number of primary branches, plant height, duration, number of fruits, fruit weight, fruit length, fruit girth and yield per plant. Also the genotypes showed wide variability for the shoot and fruit borer incidence and colour and hairiness on fruits.

The existence of high variability for several characters in okra was reported by Gondane and Lal (1994), Sindhumole *et al.* (2006), Jindal *et al.* (2010) and Reddy *et al.* (2012).

Days to 50% flowering showed considerable variation. T27 was the earliest flowering type followed by T24, T25, T28 and T30. These genotypes were early in flower production which is a desirable trait in crops like okra. Substantial variation for this character was reported by Vijay and Manohar (1990).

Leaf axil bearing first fruit ranged from 3.80 to 6.60. The duration also exhibited commendable variation, the range being 78.53 to 130.26 days.

A good amount of variation in number of primary branches was noticed among the genotypes which is agreement with the findings of Yadav (1985), Mohamed and Anbu (1997) and Singh and Singh (2006). Wide variation for plant height was noticed in the present study which is supported by the reports by Yadav (1985); Vijay and Manohar (1990); Rao (1996); Mohamed and Anbu (1997); Panda and Singh (1997); Singh and Singh (2006) and Akotkar *et al.*(2010).

Number of fruits per plant is a character which presumably has profound influence on the yield potential of the genotype. Identification of genotypes with more number of fruits per plant is very important in crop improvement programmes. Conspicuous variation was noticed for number of fruits per plant in the present study which ranged from 5.00 to 15.00. Corroborative findings were reported by Singh and Singh (1979); Murthy and Bavaji (1980); Reddy *et al.* (1985); Palve *et al.* (1985); Vijay and Manohar (1990); Rao (1996) and Mohamed and Anbu (1997).

Remarkable variation in fruit weight and fruit length was evident in present study. Fruit weight and fruit length are characters deserving intimate attention in breeding programmes for their apparent influence on yield. Existence of large extent of variability in fruit weight in okra germplasm was reported by Mohamed and Anbu (1997); Alam and Hossain (2006) and Akotkar *et al.*(2010). Following variability studies in okra, Murthy and Bavaji (1980); Singh and Singh (2006) and Akotkar *et al.*(2010) reported wide variation in fruit length.

Fruit girth is a character that showed a narrow range of variation in the present study (5.33 to 7.10 cm). Reddy *et al.* (1985); Vijay and Manohar (1990) and Rao (1996) reported low variability among the varieties evaluated in the variability studies in okra conducted by them.

Yield per plant showed impressive variation with values ranging from 103.18 g to 289.39 g. T15 was identified as the highest yielder and T5 was the lowest yielding genotype. Existence of high variability for yield per plant in okra was also reported by Singh and Singh (1979); Murthy and Bavaji (1980); Palve *et al*. (1985); Yadav (1985); Mohamed and Anbu (1997); Alam and Hossain (2006); Singh and Singh (2006) and Akotkar *et al.* (2010).

Variability is also expressed as the coefficient of variation. In the present study the PCV ranged from 6.96 for fruit girth to 39.56 for number of primary branches. The highest PCV for number of primary branches was followed by yield per plant and number of fruits while a low PCV was shown by fruit girth, days to 50% flowering and fruit length. High PCV for number of primary branches observed in this study is supported by Mishra and Chonkar (1979); Kale *et al.* (1989); Mondal and Dana (1993); Deo *et al.* (1996); Rao (1996); Mohamed and Anbu (1997); Gandhi *et al.* (2001); Jaiprakashnarayan *et al.* (2006); Singh *et al.* (2006); Vishalkumar *et al.*(2006); Singh *et al.* (2007); Saifullah and Rabbani (2009) and Jindal *et al.* (2010). Similarly high PCV for yield per plant and plant height were reported by Reddy *et al.* (1985); Balakrishnan and Balakrishnan (1988) and Vijay and Manohar (1990).

GCV is a better tool to understand useful variability, as it is free from the environmental component affecting variability. GCV ranged from 6.25 for fruit girth to 38.57 for number of primary branches. Yield per plant and number of fruits per plant also expressed high values of GCV while low values were shown by fruit girth and days to 50% flowering.

Corroborative findings of high GCV were reported for number of primary branches by Reddy *et al.* (1985); Hazra and Basu (2000) and Reddy *et al.* (2012), for yield per plant by Yadav and Chonkar (1991); Rao (1996) and Singh *et al*. (2006).

High GCV for fruit weight evident in the present study is supported by the findings of Jeyapandi and Balakrishnan (1992); Mehta *et al.* (2006) and Adiger *et al.* (2011).

Moderate GCV and PCV for fruit length were observed in the present study and it is in agreement with the findings of Mulge *et al.* (2004). However, both the PCV and GCV were low for fruit girth. Similar findings were reported by Balakrishnan and Balakrishnan (1988) and Akotkar *et al.* (2010).

High PCV as well as high GCV were observed for yield per plant and number of fruits per plant. Vijay and Manohar (1990) reported high PCV as well as high GCV for yield per plant and yield per plant. Rao (1996) also reported similar findings.

The GCV and the PCV were very close for most of the characters which indicated less environmental influence on the expression of the characters under study. The magnitude of PCV was higher than that of GCV for all the traits.

In this study, high values of PCV with correspondingly high values of GCV were observed for the characters *viz.,* number of primary branches and number of fruits per plant which indicated the presence of substantial variability thus suggesting good scope for improvement through selection.

5.1.2 Heritability and Genetic advance

The variability existing in a population is the sum total of heritable and non-heritable components. High value of heritability indicates that the phenotype of the trait strongly reflects the genotype and suggests the major role of genetic constitution in the expression of that character. Johnson *et al.* (1955) opined that the magnitude of heritability indicates the effectiveness of selection based on phenotypic performance. They further suggested that heritability and genetic advance if considered together would make selection more effective. Burton (1952) suggested that GCV along with heritability would provide a clear idea about the amount of genetic advance expected by selection.

In the present study, all the characters showed high heritability estimates (80.64 to 99.58 per cent). Heritability was maximum for duration followed by fruit weight, plant height, fruit length, yield per plant, number of fruits per plant, days to 50 per cent flowering, number of primary branches, leaf axil bearing first fruit and fruit girth.

High heritability for fruit weight seen in the present investigation is in accordance with the reports by Palaniveluchamy *et al.* (1982); Balakrishnan and Balakrishnan (1988); Jeyapandi and Balakrishnan (1992); Mohamed and Anbu (1997); Hazra and Basu (2000); Mehta *et al.* (2006); Saifullah and Rabbani (2009); Prakash and Pitchaimuthu (2010); Adiger *et al.* (2011) and Reddy *et al.* (2012).

High heritability estimated for plant height and fruit length in the present study is well supported by the corroborative reports by several workers [Murthy and Bavaji (1980); Dhall *et al.* (2000); Mehta *et al.* (2006) and Reddy *et al.* (2012)].

Yield improvement is the ultimate objective of any breeding programme. Hence yield can be considered as the most important among the characters studied. High heritability for yield per plant was noted in the present study. The variability for yield among the accessions evaluated was also impressive. This implies that worthwhile improvement can be achieved through selection. In addition to yield per plant, number of fruits per plant also registered high estimate of heritability in the present study. Corroborative reports of high heritability for the above two characters by Singh and Singh (1979); Palve *et al*. (1985); Balakrishnan and Balakrishnan (1988); Jeyapandi and Balakrishnan (1992); Mohamed and Anbu (1997); Mulge *et al.* (2004); Singh *et al.* (2006); Vishalkumar *et al.* (2006); Sindhumole *et al.* (2006); Saifullah and Rabbani (2009) and Reddy *et al.* (2012) supports the findings in the present study.

High heritability for days to 50% flowering in the present investigation is in accordance with the reports by Jaiprakashnarayan *et al.* (2006); Prakash and Pitchaimuthu (2010); Adiger *et al.* (2011) and Reddy *et al.* (2012).

Number of primary branches recorded high heritability. Corroborative reports by Mishra and Chonkar (1979); Nair and Sheela (1985); Reddy *et al.* (1985); Kale *et al.* (1989); Mohamed and Anbu (1997); Hazra and Basu (2000); Singh *et al.* (2006); Singh and Singh (2006); Vishalkumar *et al.* (2006); Saifullah and Rabbani (2009); Jindal *et al.* (2010) and Reddy *et al.* (2012) support the present finding.

Report by Gandhi *et al.* (2001) supports the high heritability values for fruit girth recorded in the present study.

High estimates of genetic advance as percentage of mean were recorded for number of primary branches and yield per plant. High genetic advance as percentage of mean for the above mentioned characters were also reported by several workers (Reddy *et al.* (1985); Singh *et al.* (2006); Singh and Singh (2006); Vishalkumar *et al.* (2006); Akotkar *et al.* (2010) and Reddy *et al.* (2012).

High estimates of genetic advance as percentage of mean were also recorded for number of fruits per plant, fruit weight, plant height, duration, leaf axil bearing first fruit, fruit length and fruit weight in the present study.

High genetic gain for number of fruits per plant as observed in the study were reported by numerous workers, Some of the recent reports include those by Dhall *et al.* (2000); Mulge *et al.* (2004); Singh *et al.* (2006); Vishalkumar *et al.* (2006); Akotkar *et al.* (2010) and Reddy *et al.* (2012). High genetic advance for fruit weight reported by Balakrishnan and Balakrishnan (1988); Hazra and Basu (2000); Mehta *et al.* (2006); and Reddy *et al.* (2012) is in conformity with the present finding.

Recent reports of high genetic gain for plant height that are in conformity with the present finding include these by Mehta *et al.* (2006); Singh *et al.* (2006); Vishalkumar *et al.* (2006); Akotkar *et al.* (2010) and Reddy *et al.* (2012) supports the high genetic gain for plant height.

Earlier reports of high genetic gain for fruit length by Palve *et al.* (1985); Dhall *et al.* (2000); Mehta *et al.* (2006); Singh *et al.* (2006); Reddy *et al.* (2012) support the findings in this investigation.

High heritability along with high genetic advance indicates additive gene action for the characters under consideration, which implies the possibility for its genetic improvement through selection (Panse, 1957). In the present study, high heritability coupled with high genetic advance was observed for fruit characters *viz.,* fruit weight and fruit length. Earlier reports supporting this findings include those by Mehta *et al.* (2006) and Reddy *et al.* (2012). Plant growth characters *viz*., plant height and number of primary branches registered high heritability and high genetic advance in the present investigation. Earlier reports by Reddy *et al.* (1985); Singh *et al.* (2006) and Reddy *et al.* (2012) are in conformity with the present findings.

Number of fruits per plant and yield per plant registered high heritability and high genetic advance in the present study. Corroborative reports of high heritability coupled with high genetic advance for the above two characters by Singh and Singh (1979); Palve *et al.* (1985); Balakrishnan and Balakrishnan (1988); Mohamed and Anbu (1997); Mulge *et al.* (2004); Singh *et al.* (2006); Singh and Singh (2006); Vishalkumar *et al.* (2006) and Reddy *et al.* (2012) supports the present findings.

From the foregoing discussion it is evident that the characters *viz*., yield per plant, number of fruits per plant, number of primary branches, fruit weight and fruit length offer immense scope for improvement through selection on account of their high magnitude of heritability and exceptionally high genetic advance.

5.1.3 Correlation studies

Yield is a complex character influenced by many characters either in positive or negative direction. So selection for yield should take into account related characters as well. Correlation provides information on the nature and extent of relationship between pairs of characters. Therefore, analysis of yield in terms of genotypic and phenotypic correlation coefficients of component characters leads to the understanding of characters that can form the basis of selection. The genotypic correlation between characters provides a reliable measure of the genetic association between characters and helps to differentiate the vital association useful in breeding from non-vital ones (Falconer, 1981).

a. Correlation between yield and other characters

In the present investigation, yield per plant showed strong genotypic correlation with number of fruits per plant (0.7392), fruit weight (0.3212) and fruit girth (0.4750). The positive association of yield per plant with number of fruits per plant in this study is supported by corroborative reports by several workers [Dhall *et al,.* (2000), Dhankhar and Dhankhar (2002), Jaiprakashnarayan and Mulge (2004), Sindhumole *et al.* (2006), Singh *et al.* (2006), Ramya and Senthilkumar (2009), Guddadamath *et al.* (2011), Adiger *et al.* (2011)].

Earlier reports of high positive genotypic correlation of yield per plant with fruit weight and fruit girth by Nair and Sheela (1985), Jeyapandi and Balakrishnan (1990), Patel and Dalal (1994), Dash and Mishra (1995), Sindhumole *et al.* (2006) and Singh *et al.* (2006) supports the present findings.

Murthy and Bavaji (1980), Yadav (1985) and Vijay and Manohar (1990), Dhankhar and Dhankhar (2002) reported significant negative correlation of yield with days to 50% flowering as noticed in the present study.

Significant positive phenotypic and genotypic correlations of yield per plant with fruits per plant, fruit weight and fruit girth imply that selection for these characters would lead to simultaneous improvement for yield per plant in okra. High heritability of the above mentioned characters further support the notion, since for highly heritable characters, the phenotypic value of a genotype tend to reflect its genotypic worth.

b. Correlation among the yield component characters

Knowledge of the inter-relationships among the yield components is necessary since it provides more reliable information for effective selection based on yield components.

Plant height and duration showed positive significant genotypic correlation among themselves which is in agreement with the findings of Reddy *et al.* (1985). Fruit weight and fruit length also had significant genotypic correlation between them and this finding is supported by the reports of Maksoud *et al.* (1984). Number of fruits per plant had positive genotypic correlation with fruit girth. Maksoud *et al.* (1984), Reddy *et al.* (1985), Patel and Dalal (1994) supports the above finding.

It is noteworthy that the present study suggested highly significant negative correlation between number of fruits per plant and fruit weight both at genotypic and phenotypic levels. Adiger *et al.* (2011) supports the present finding.

It is noteworthy that number of fruits per plant and fruit girth besides being positively associated with yield, showed positive genotypic correlation between them (0.3498). These two characters had high heritability. Hence it would be worthwhile to give due consideration to these characters in selection programmes aimed at yield improvement.

c. Correlation among shoot and fruit borer damage parameters

The results suggested that there was no relationship between per cent shoot infestation and other damage parameters *viz*., per cent fruit infestation and larval count in 25 fruits.

Highly significant positive correlation between per cent fruit infestation and larval count in 25 fruits in the present study suggest that either of the fruit damage criteria may be employed for the evaluation of shoot and fruit borer resistance in okra.

5.1.4 Screening for shoot and fruit borer resistance

Okra is attacked by many insect pests of which shoot and fruit borer, *E. vittella* (Lepidoptera : Noctuidae) is a major pest. The larvae bore into growing shoots, buds and tender fruits resulting in their shedding and consequently affecting the fruit quality and yield to a considerable extent. Most of the present day cultivars are susceptible to this pest (Gupta and Yadav, 1978).

Host plant resistance is an economic and eco-friendly pest control tactic. Varieties suffering lesser damage in comparison with others under identical pest population pressure can be considered relatively resistant. Even a low level of plant resistance can substantially reduce the dependence on chemical protection and hence regarded as highly beneficial. Nowadays, damage based resistance evaluation is widely employed for varietal screening for pest resistance. Hence this screening programme for identifying okra genotypes suffering lesser damage from shoot and fruit borer attack was taken up.

According to Tingey (1986) assessment of plant resistance through measurement of insect damage should be made employing damage criteria closely associated with the ultimate loss in crop yield and quality. Tender shoots and fruits being the primary feeding sites of the shoot and fruit borer larvae the damage to them together would ideally reflect the ultimate crop loss due to the pest.

There were significant differences among the genotypes for all damage parameters studied *viz.,* percentage shoot infestation, percentage fruit infestation and larval counts in fruits. Significant differences among okra genotypes in shoot and fruit borer damage was also reported by Shukla, *et al.* (1997); Srinivasa and Sugeetha (2001) and also Jalgaonkar *et al.* (2002).

The genotypes which recorded the highest shoot infestation percentage were T_{16} and T_{24}. They suffered ten times shoot damage compared to the least affected genotypes T_{22} and T_{23}. Several workers reported wide variation in shoot infestation by the pest among the genotypes in resistance screening programmes undertaken by them (Raut and Sonone 1979, Pandey *et al.* 2002, and Sharma and Jat, 2009).

Since the shoot and fruit borer larvae tend to migrate from one fruit to other, simultaneous infestation of more than one fruit in the same plant is a most commonly noticed symptom. T_9 was found to have the least fruit infestation followed by T_5. Highest fruit infestation percentage was recorded for T_1 and T_{25}. Eight other genotypes (T_2, T_3, T_6, T_{12}, T_{24}, T_{26}, T_{28} and T_{29}) also recorded high fruit damage comparable to T_1 and T_{25}.

Larval count in fruits is another damage assessment criterion employed in the present study. The genotypes T_1 and T_{29} recorded the highest larval counts in fruits which is as high as 9.66 larvae in 25 fruits. The larval count was lowest in T_9 in which only one larva could be recovered from the 25 fruits examined.

In the present study, field screening for shoot and fruit borer resistance was based on percentage shoot infestation, percentage fruit infestation and larval counts in fruits. The genotypes T_1, T_2 , T_{24} and T_{25} were found to suffer severe damage on all the three damage assessment criteria employed.

Fruit damage assessement based on percentage fruit infestation as well as larval count in fruits indicated T_9 as the accession suffering the least fruit damage irrespective of the criterion employed for damage assessment. However, T_9 was found to suffer significantly higher shoot damage in comparison with T_{22} and T_{23}, the genotypes suffering least shoot damage. But the fruits of T_{22} and T_{23} were found to be severely infested by the pest. Overall consideration of damage assessment indicated T_9 as a worthwhile genotype with regard to shoot and fruit borer resistance. This observation was further supported by the result of the laboratory experiment conducted to assess the larval feeding preferences which also suggested that the accession T_9 as the least preferred.

T_{15} was the highest yielder among the accessions evaluated but found to be considerably damaged by shoot and fruit borer infestation. On the other hand, T_9 adjudged as the accession with the highest level of resistance to the pest was poor yielding. Combination breeding efforts utilizing T_{15}, the highest yielder among the accessions evaluated and T_9 as the shoot and fruit borer resistance source would hopefully lead to development of high yielding shoot and fruit borer resistant genotypes of okra.

SUMMARY

6. SUMMARY

The present study entitled "Evaluation of okra [*Abelmoschus esculentus* (L.) Moench] genotypes for yield and resistance to shoot and fruit borer, *Earias vittella* (Fab.)" was conducted at the Department of plant breeding and genetics, College of Agriculture, Vellayani during the period 2010-2012.

Thirty one genotypes of okra collected from different sources were evaluated for yield and resistance to shoot and fruit borer in a field experiment in randomized block design with three replications. Observations were recorded on 13 characters *viz*., days to 50% flowering, leaf axil bearing first fruit, number of primary branches, plant height, duration, number of fruits per plant, fruit weight, fruit length, fruit girth, yield per plant, shoot infestation, fruit infestation and number of larvae per 25 fruits.

Analysis of variance revealed significant differences among the genotypes for all the thirteen characters studied. The genotype T_{15} recorded the highest yield per plant (289.39 g). T_5 was the lowest yielding genotype (103.18 g). Number of fruits per plant was highest for T_{19} (15.00) while fruit weight was maximum for T_6 (30.35g).

The genotypic variance made up the major portion of phenotypic variance for all the characters studied. PCV and GCV were high for plant height, yield per plant, fruit weight and number of fruits per plant while both were low for days to 50 per cent flowering, number of primary branches, leaf axil bearing first fruit, duration and fruit length.

The heritability estimates were high for all the thirteen characters and it ranged from 80.64 to 99.58 per cent. High values of heritability coupled with high genetic advance were observed for leaf axil bearing first fruit, number of primary branches, plant height, duration, fruit weight, fruit length and yield per plant. High heritability and genetic advance for yield and yield contributing characters *viz*., number of fruits per plant and fruit weight indicate scope for improvement of yield through selection.

Both at phenotypic and genotypic levels, yield per plant showed high positive correlation with number of fruits per plant, fruit weight and fruit girth. Number of fruits per plant had the highest correlation with yield both at phenotypic as well as genotypic levels.

In the study shoot and fruit borer resistance evaluation was done comparing the damage suffered by the accessions consequent to natural infestation under field condition. Significant differences were observed among the genotypes for all the damage parameters employed for resistance evaluation *viz*., percentage shoot infestation, percentage fruit infestation and larval count in 25 fruits. Fruit damage in terms of both percentage fruit infestation and larval count in 25 fruits was highest for T_1 and lowest for T_9. The genotypes T_{22} and T_{23} recorded the lowest percentage shoot infestation. Highest percentage shoot infestation was observed for genotypes T_{16} and T_{24}. The genotypes T_1, T_2, T_{24} and T_{25} were found to suffer severe damage on all the three damage assessment criteria employed.

Highly significant positive correlation between per cent fruit infestation and larval count in 25 fruits evident from the present study suggest that either of the fruit damage criteria may be employed for the evaluation of shoot and fruit borer resistance in okra.

Fruit damage assessed based on percentage fruit infestation as well as larval count in fruits indicated T_9 as the accession suffering the least fruit damage irrespective of the criterion employed for damage assessment. However, T_9 was found to suffer significantly higher shoot damage in comparison with T_{22} and T_{23}, the genotypes suffering least shoot damage. But the fruits of T_{22} and T_{23} were found to be severely infested by the pest. Overall consideration of damage assessment indicated T_9 as a worthwhile genotype with regard to shoot and fruit borer resistance. This observation was further supported by the result of the laboratory experiment conducted to assess the larval feeding preferences which also suggested that the accession T_9 as the least preferred.

T_{15} was the highest yielder among the accessions evaluated but found to be susceptible to shoot and fruit borer infestation. On the other hand, T_9 adjudged as the accession with the highest level of resistance to the pest was poor yielding. Combination breeding efforts utilizing T_{15}, the highest yielder among the accessions evaluated and T_9 as the shoot and fruit borer resistance source would hopefully lead to development of high yielding shoot and fruit borer resistant genotypes of okra.

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ABSTRACT

EVALUATION OF OKRA [*Abelmoschus esculentus* (L.) Moench] GENOTYPES FOR YIELD AND RESISTANCE TO SHOOT AND FRUIT BORER, *Earias vittella* (Fab.)

by

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ABSTRACT

The research project entitled "Evaluation of okra [*Abelmoschus esculentus* (L.) Moench] genotypes for yield and resistance to shoot and fruit borer, *Earias vittella* (Fab.)" was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 2011-2012. The study aimed at the evaluation of a collection of okra genotypes for shoot and fruit borer resistance and yield to identify high yielding shoot and fruit borer resistant genotypes, if available among them.

Thirty one genotypes of okra collected from different sources were evaluated for yield and resistance to shoot and fruit borer in a field experiment in randomized block design with three replications. Observations were recorded on 13 characters *viz*., days to 50% flowering, leaf axil bearing first fruit, number of primary branches, plant height, duration, number of fruits per plant, fruit weight, fruit length, fruit girth, yield per plant, shoot infestation, fruit infestation and number of larvae per 25 fruits.

Analysis of variance revealed significant differences among the genotypes for all the thirteen characters studied. Also the genotypes showed wide variation for the shoot and fruit borer infestation.

In this study, high values of PCV with correspondingly high values of GCV were observed for the characters *viz*., number of primary branches and number of fruits per plant which indicated the presence of substantial variability for these characters. High magnitude of heritability coupled with high genetic advance for the characters *viz*., yield per plant, number of fruits per plant, number of primary branches, fruit weight and fruit length suggested the scope for improvement of these characters through selection.

Both at phenotypic and genotypic levels, yield per plant showed high positive correlation with number of fruits per plant, fruit weight and fruit girth which implies that selection for these characters would lead to simultaneous improvement for yield per plant in okra.

In the present study, shoot and fruit borer resistance evaluation was done comparing the damage suffered by the accessions consequent to natural infestation under field condition. Significant differences were observed among the genotypes for all the damage parameters employed for resistance evaluation *viz*., percentage shoot infestation, percentage fruit infestation and larval count in 25 fruits. Fruit damage in terms of both percentage fruit infestation and larval count in 25 fruits was highest for T_{1} and lowest for T_{9}. The genotypes T_{22} and T_{23} recorded the lowest percentage shoot infestation. Highest percentage shoot infestation was observed for genotypes T_{16} and T_{24}. The genotypes T_{1}, T_{2}, T_{24} and T_{25} were found to suffer severe damage on all the three damage assessment criteria employed.

Fruit damage assessed based on percentage fruit infestation as well as larval count in fruits indicated T_{9} as the accession suffering the least fruit damage irrespective of the criterion employed for damage assessment. However, T_{9} was found to suffer significantly higher shoot damage in comparison with T_{22} and T_{23}, the genotypes suffering least shoot damage. But the fruits of T_{22} and T_{23} were found to be severely attacked by the pest. Overall consideration of damage measurements indicate T_{9} as a worthwhile genotype with regard to shoot and fruit borer resistance. This notion is further supported by the result of the laboratory experiment conducted to get an insight into the larval feeding preferences which suggested T_{9} as the accession least preferred by the larvae for feeding.

Highly significant positive genotypic correlation between per cent fruit infestation and larval count in the fruits evident from the present study suggests that either of the fruit damage criteria may be employed for the evaluation of shoot and fruit borer resistance in okra.

T_{15} was the highest yielder among the accessions evaluated but found to suffer considerable damage from shoot and fruit borer infestation. On the other hand, T_9 adjudged as the accession with the highest level of resistance to the pest was poor yielding. Combination breeding efforts utilizing T_{15}, the highest yielder among the accessions evaluated and T_9 as the shoot and fruit borer resistance source would hopefully lead to development of high yielding shoot and fruit borer resistant genotypes of okra.