

**GENETIC VARIABILITY STUDIES IN GROUNDNUT FOR TOLERANCE
TO LEAF MINER (*Aproaerema modicella* D.)**

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UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL SCIENCES
SHIVAMOGGA**

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Thesis submitted to the
**KELADI SHIVAPPA NAYAKA
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**DEPARTMENT OF GENETICS AND PLANT BREEDING
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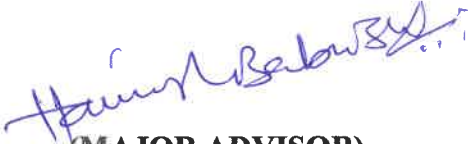
CERTIFICATE

This is to certify that the thesis entitled '**GENETIC VARIABILITY STUDIES IN GROUNDNUT FOR TOLERANCE TO LEAF MINER (*Aproaerema modicella* D.)**' submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **GENETICS AND PLANT BREEDING** to the College of Agriculture, Shivamogga, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga is a bonafide record of research work carried out by **Preethi L. R., ID. No. MA1TBA0466** (preethilr123@gmail.com) during the period of study in this university under my guidance and supervision and no part of this thesis has previously formed the basis for the award of any other degree, diploma, associateship, fellowship or any other similar titles.

Shivamogga

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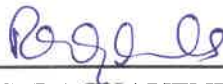


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Genetic Variability Studies in Groundnut for Tolerance to Leaf Miner
(*Aproaerema modicella* D.)

(Preethi L. R.)

ABSTRACT

A field experiment was conducted during early *Rabi* 2022 at the ZAHRS, Hiriyyur to screen 34 groundnut genotypes for tolerance to leaf miner (*Aproaerema modicella*) under field condition. The genotypes were sown in a RCBD with 2 replications each in control (with suitable pest control measures) and leaf miner stress (without any pest control measures). Visual observations were made on *percent* foliage damage (0-100%) due to leaf miner infestation at four stages *i.e.*, 30, 60, 90 days after sowing and at maturity by following the standard 1-10 scale for categorization of genotypes. ANOVA for damage score based on *percent* foliage damage revealed high GCV and PCV, high heritability coupled with high genetic advance as *per cent* mean (GAM) at all the four stages. Among the characters assessed, most of the traits exhibited decrease in *per cent* mean under leaf miner infestation when compared with that of control for days to maturity, number of mature pods per plant, pod yield per plant, kernel yield per plant, pod yield per hectare, kernel yield per hectare and haulm yield per plant. The results of field screening of groundnut genotypes against leaf miner revealed that, the genotypes K-1812 and R-2001-3 were tolerant with a least foliage damage, whereas K-9, HG 2023, R-8808, KDG-128 and Dh-256 were found to be moderately tolerant and remaining genotypes were susceptible. A wide range of variability and high heritability coupled with high GAM were recorded for most of the yield contributing traits. The association studies revealed that, pod yield recorded significant and positive association with plant height, number of primary branches per plant, number of mature pods per plant, haulm yield per plant, shelling percentage, kernel yield per plant, kernel yield per hectare, test weight and pod yield per hectare and negative significant association with leaf miner damage.

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ಶೇಂಗಾದಲ್ಲಿ ಎಲೆ ಕೊರೆಯುವ ಹುಳದ ಸಹಿಷ್ಣುತೆಗಾಗಿ ಅನುವಂಶೀಯ ವಿಭಿನ್ನತೆಯ ಅಧ್ಯಯನ

(ಪ್ರೀತಿ ಎಲ್. ಆರ್.)

ಸಾರಾಂಶ

ಶೇಂಗಾದಲ್ಲಿ ಪರಿಣಾಮಕಾರಿ ಬೆಳೆ ಸುಧಾರಣೆಗೆ ಅನುವಂಶೀಯ ಅಧ್ಯಯನ ಮತ್ತು ಎಲೆ ಕೊರೆಯುವ ಹುಳ ಸಹಿಷ್ಣು ಬಹಳ ಮುಖ್ಯ. ಎಲೆ ಕೊರೆಯುವ ಹುಳ ಸಹಿಷ್ಣು ಶೇಂಗಾ ವಂಶವಾಹಿ ರೂಪದ ತಳಿಗಳನ್ನು ಮೌಲ್ಯಮಾಪನ ಮಾಡಲು ಮತ್ತು ಗುರುತಿಸಲು ೨೦೨೨ ರ ತಡೆ ಹಿಂಗಾರು ಋತುವಿನಲ್ಲಿ ಹಿರಿಯೂರಿನ ವಲಯ ಕೃಷಿ ಮತ್ತು ತೋಟಗಾರಿಕೆ ಸಂಶೋಧನಾ ಕೇಂದ್ರದಲ್ಲಿ, ಪ್ರತಿಯೊಂದು ನಿಯಂತ್ರಣ (ಸೂಕ್ತ ಕೀಟ ನಿಯಂತ್ರಣ ಕ್ರಮಗಳೊಂದಿಗೆ) ಹಾಗೂ ಎಲೆ ಕೊರೆಯುವ ಹುಳದ ಒತ್ತಡ (ಕೀಟ ನಿಯಂತ್ರಣ ಕ್ರಮಗಳು ಇಲ್ಲದೆ) ಎರಡು ಪ್ರತಿಕ್ರಿಯೆಗಳೊಂದಿಗೆ ಯಾದೃಚ್ಛಿಕಗಳನ್ನು ಸಂಪೂರ್ಣ ಬ್ಲಾಕ್ ವಿನ್ಯಾಸದಲ್ಲಿ ಶೇಂಗಾದ ೩೪ ವಂಶವಾಹಿ ರೂಪಗಳನ್ನು ಬಳಸಿಕೊಂಡು ತನಿಖೆಯನ್ನು ನಡೆಸಲಾಯಿತು. ಶೇಕಡಾವಾರು ಎಲೆ ಹಾನಿ ಆಧಾರಿತ ದೃಶ್ಯ ವೀಕ್ಷಣೆಯನ್ನು ಎಲೆ ಕೊರೆಯುವ ಹುಳದಿಂದಾದ ಹಾನಿಯನ್ನು ೪ ಹಂತದಲ್ಲಿ ವಿಶ್ಲೇಷಣೆ ಮಾಡಲಾಯಿತು. ಇದರ ಆಧಾರದ ಮೇಲೆ ವಂಶವಾಹಿ ರೂಪಗಳಾದ ಕೆ-೧೮೧೨ ಮತ್ತು ಆರ್-೨೦೦೧-೩ ಕಡಿಮೆ ಎಲೆ ಹಾನಿಯಿಂದ ಎಲೆ ಕೊರೆಯುವ ಹುಳ ಸಹಿಷ್ಣು ಎಂದು ಗುರುತಿಸಲಾಗಿದೆ. ಹಾಗೆ ಕೆ-೯, ಎಚ್‌ಜಿ - ೨೦೨೩, ಆರ್-೮೮೦೮, ಕೆಡಿಜಿ-೧೨೮ ಮತ್ತು ಡಿಎಚ್-೨೫೬ ಗಳನ್ನು ಮಧ್ಯಮ ಸಹಿಷ್ಣುಗಳೆಂದು ಗುರುತಿಸಲಾಗಿದೆ. ವ್ಯತ್ಯಾಸದ ವಿಶ್ಲೇಷಣೆಯು ಅಭ್ಯಸಿಸಿದ ಎಲ್ಲಾ ಗುಣಲಕ್ಷಣಗಳಿಗೆ ಅಧ್ಯಯನದ ಅಡಿಯಲ್ಲಿ ವಂಶವಾಹಿ ರೂಪಗಳ ನಡುವೆ ಗಮನಾರ್ಹ ವ್ಯತ್ಯಾಸಗಳ ಅಸ್ತಿತ್ವವನ್ನು ಬಹಿರಂಗಪಡಿಸಿತು. ಇಳುವರಿಗೆ ಸಂಬಂಧಿಸಿದ ಬಹುತೇಕ ಗುಣಲಕ್ಷಣಗಳಿಗೆ ಅತ್ಯಧಿಕ ವ್ಯತ್ಯಾಸ, ಹೆಚ್ಚಿನ ಅನುವಂಶೀಯ ಸಾಮರ್ಥ್ಯದ ಜೊತೆಗೆ ಹೆಚ್ಚಿನ ಸರಾಸರಿ ಅನುವಂಶೀಯ ಮುಂಚಲನ ಕಂಡು ಬಂದಿರುತ್ತದೆ. ಪರಸ್ಪರ ಸಂಬಂಧದ ಅಧ್ಯಯನದಲ್ಲಿ ಪ್ರತಿ ಗಿಡದ ಕಾಯಿಗಳ ಇಳುವರಿಯ ಸಸ್ಯದ ಎತ್ತರ, ಪ್ರತಿ ಗಿಡದ ಪ್ರಾಥಮಿಕ ಕೊಂಬೆಗಳ ಸಂಖ್ಯೆ, ಪ್ರತಿ ಗಿಡದ ಪ್ರಬುದ್ಧ ಕಾಯಿಗಳ ಸಂಖ್ಯೆ, ಹಲ್ಮ್ ಇಳುವರಿ, ಸರಾಸರಿ ಶೇಕಡ ಕಾಳಿನ ಇಳುವರಿ, ಪ್ರತಿ ಗಿಡದ ಬೀಜದ ಇಳುವರಿ, ಪ್ರತಿ ಹೆಕ್ಟೇರ್ ಬೀಜದ ಇಳುವರಿ, ೧೦೦ ಬೀಜದ ತೂಕ ಮತ್ತು ಪ್ರತಿ ಹೆಕ್ಟೇರ್‌ನ ಕಾಯಿಗಳ ಇಳುವರಿಯು ಗಮನಾರ್ಹ ಧನಾತ್ಮಕ ಸಂಬಂಧವನ್ನು ತೋರಿದೆ. ಅಭ್ಯಸಿಸಿದ ಎಲ್ಲಾ ಗುಣಲಕ್ಷಣಗಳಲ್ಲಿ ಬಹುತೇಕ ಗುಣಲಕ್ಷಣಗಳು ಎಲೆ ಕೊರೆಯುವ ಹುಳದ ಒತ್ತಡವನ್ನು ನಿಯಂತ್ರಣಕ್ಕೆ ಹೋಲಿಸಿದರೆ ಶೇಕಡಾ ಸರಾಸರಿಯಲ್ಲಿ ಇಳಿಕೆಯು ದೃಢೀಕರಣಕ್ಕೆ ಬೇಕಾದ ದಿನಗಳು, ಪ್ರತಿ ಗಿಡದ ಪ್ರಬುದ್ಧ ಕಾಯಿಗಳ ಸಂಖ್ಯೆ, ಪ್ರತಿ ಗಿಡದ ಕಾಯಿಗಳ ಇಳುವರಿ, ಪ್ರತಿ ಹೆಕ್ಟೇರ್‌ನ ಬೀಜದ ಇಳುವರಿ ಮತ್ತು ಪ್ರತಿ ಗಿಡದ ಹಲ್ಮ್ ಇಳುವರಿ ಮುಂತಾದ ಗುಣಲಕ್ಷಣಗಳಲ್ಲಿ ಕಂಡು ಬಂದಿರುತ್ತದೆ.

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INTRODUCTION

I INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is the world's fourth most important source of edible oil and third most important source of vegetable protein. It is an important commercial crop of rainfed areas and contributes to around 40 *per cent* of the total oilseeds production. Groundnut is an annual legume crop known for its nutritional contents. It is a self-pollinated, allotetraploid ($2n=4X=40$), belongs to leguminosae family. Groundnut is cultivated in more than 100 countries over an area of 29.6 million hectares with a production of 48.7 million tonnes accounting to a productivity of 1,647 Kg/ha (Anonymous, 2020). India ranks first in groundnut acreage and is the second largest producer of groundnut in the world with 10.1 million tonnes with a productivity of 1,816 Kg/ha during 2020-21 (Anonymous, 2021). In India, groundnut is grown in an area of 4.82 million hectares with a production 9.95 million tonnes and productivity is 2,063 Kg/ha. Gujarat is the largest producer of groundnut with an area of 1.62 million hectares, producing 4.64 million tonnes with a productivity of 2,751 Kg/ha and Karnataka stands fifth in position with an area of 0.504 million hectares, 502.81 million tonnes of production and productivity of 998 Kg/ha (Anonymous, 2021).

The low level of groundnut productivity in India is largely because, the crop is raised under rainfed conditions. Groundnut is considered by farmers as the most remunerative crop with relatively low chance of crop failures despite unpredictable monsoons. But the insect pests and diseases form the important constraints in its production. Collar rot and tikka are important diseases, while white grubs (*Holotrichia spp.*), thrips and leaf miner (*A. modicella*) are the important insect pests of groundnut.

About two thirds of the world production of groundnut seed is used for the extraction of oil. Groundnut seeds contain high quality edible oil (35-55 %) that varies depending on variety, season and maturity (Patidar and Nadaf, 2017). The groundnut kernel contains fat (40–55 %), protein (20 to 30 %) and carbohydrates (10–20 %) along with other nutritional components like vitamin E, niacin, zinc, iron, calcium, magnesium, phosphorus, riboflavin, thiamine and potassium (Shasidhar *et al.*, 2020).

Aproaerema modicella D., *Spodoptera litura* Fabricius and *Helicoverpa armigera* Hubner are the major defoliators of groundnut (Sahayaraj and Amalraj, 2006) causing considerable economic loss. The groundnut leaf miner, *Aproaerema modicella* Deventer (Gelechiidae: Lepidoptera) is a serious insect pest of groundnut in rainy and post rainy seasons in India. It is an oligophagous insect pest feeding on leguminous plants and damaging crop especially during rainfed situation (Reddy, 1988 and Praveena *et al.*, 2011). The leaf miner is considered as the most important insect pest of groundnut in India and particularly in rainfed situations (Ayyar, 1963; Nair, 1975; Reddy, 1988). The pest initially appears as a leaf miner causing short blister like mines.

Older larvae fold the leaflets and feed within. As a result, the leaflets turn brown, shrivel and dry up. Severely infested crop gives a burnt-up appearance and yield losses can reach up to 76 *per cent* (Anonymous, 1986). More than 50 *per cent* pod yield loss due to leaf miner was reported in Tamil Nadu, India (Logiswaran and Mohanasundaram, 1985). Development of resistant varieties in order to curb the economic losses weighed by this pest becomes the best practice in the IPM package. Thus, combined efforts by plant breeders and entomologists to develop cost effective, pest-resistant/tolerant genotype is the pressing priority.

The presence of genetic variability for different traits is an important prerequisite for any crop improvement programme. Hence, ascertaining the variability for tolerance to leaf miner, yield and its components provides an insight into the extent of variability for the concerned trait and subsequent selection for the desired genotype.

In any plant breeding programme, it is essential to know the association among yield and yield related traits in the material generated, for effectual selection. Selection based on simply inherited and highly heritable yield attributes is most effective and reliable approach as compared to direct selection on yield itself. Understanding the nature and extent of association of different yield components with yield and inter relationship among themselves is an essential prerequisite for the formulation of breeding procedure for effective improvement of yield (Prabhu *et al.*, 2016).

With this background, the present investigation was undertaken with the following objectives:

- 1) To screen groundnut genotypes for tolerance to leaf miner under field condition
- 2) To assess the genetic variability of yield and its attributes in groundnut genotypes
- 3) To assess the association of yield and other traits in groundnut genotypes

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

A critical estimate of nature and magnitude of genetic variability is a prerequisite for any crop improvement programme. The variability observed in any population could be due to the genetic and environmental factors and also due to interaction between these factors. The genetic and environmental components of variation were discussed by Johansen (1909) who attributed the variation in a segregating population to heritable and non- heritable factors, while the variation within purelines was attributed to environmental factors. This was later confirmed by Nelson-Ehle (1909) and East (1916).

Groundnut has been cultivated on a large scale in central dry zone (Zone-IV) of Karnataka with an area of > 1.5 lakh ha per annum. However, its productivity is low when compared to national average which is mainly due to abiotic and biotic stresses coupled with poor management practices. There is a need to identify pest resistant variety.

The present study aims to assess the genotypes for their variability and correlation for yield attributing traits and variability study for tolerance to leaf miner to identify suitable lines for either direct utilization as varieties or as parents in hybridization programme. The literature pertaining to the set objectives of this study is reviewed under the following headings.

- 2.1 Tolerance to leaf miner in groundnut under field condition
- 2.2 Genetic variability in groundnut for yield and its attributes
- 2.3 Character association of yield and other traits in groundnut

2.1 Tolerance to leaf miner in groundnut under field condition

Nine groundnut genotypes ICG 5040, ICGV 86031, ICG 2271, NCAc 17090, Robut 33-1, ICG (FDRS) 10, ICG 2741, ICGS 44 and ICG 221 were artificially screened against groundnut leaf miner (GLM) in glasshouse and screenhouse by Rao (2002). Among the genotypes, ICG 5040 was found to be more attractive for egg laying probably as a result of its hairiness. Susceptible genotype ICG 221 had higher number of larvae and pupae per plant. ICG 5040 genotype was found to have some antibiosis factor affecting the larval survival and pupal mass of GLM.

Praveena *et al.* (2011) assessed 25 genotypes by visual grading of damage and absolute insect count on each entry. Field screening of groundnut varieties against leaf miner revealed that the genotypes Dh-4-3, ICGS-11, R-9227, R-8808 and R-9214 were moderately resistant with 25 to 35 *per cent* foliage damage and higher pod yield whereas Dh-107, Dh-112, GPBD-3, R-2001-2, TAG-04 and Dh-116 were moderately susceptible with 45 to 60 *per cent* foliage damage.

Twenty-five groundnut genotypes were field screened for leaf miner and defoliator incidence by Arunachalam and Kavitha (2012). Incidence of leaf miner was increased with a rise in maximum temperature and decrease in relative humidity, rainfall and leaf wetness. The field screening results revealed that, less leaf miner incidence was recorded in the genotypes *viz.*, ICGV 06424, ICGV 07220, ICGV 07222, ICGV 07240, ICGV 07245, ICGV 07247, ICGV 07268, ICGS 11 and VRI (Gn) 6.

Saheb *et al.* (2020) screened different groundnut genotypes for tolerance to leaf miner. Groundnut leaf miner is an oligophagous pest that feeds on leguminous host plants and also on groundnut both in rainy and post rainy season in India and the yield losses can reach up to 76 *per cent*. Based on the incidence of this pest, genotypes TCGS-894 and TCGS-1097 were ranked as highly resistant, ASK-2013-1 was ranked as moderately resistant and Narayani, K-1563, K-4 and Dharani were ranked as susceptible towards their reaction to groundnut leaf miner.

Screening of groundnut (*Arachis hypogaea* L.) genotypes against *Aproaerema modicella* was conducted by Waykule *et al.* (2020). Among 50 germplasm lines screened, two of the entries were found highly resistant against *Aproaerema modicella* larvae and twelve germplasm lines were categorized as resistant. Fourteen germplasm lines were found as moderately resistant and twelve as susceptible while ten germplasm lines were found highly susceptible to *Aproaerema modicella* larvae. The check JL-24 was found susceptible to *Aproaerema modicella* larvae.

Rahman *et al.* (2021) screened forty germplasm lines of groundnut for leaf miner. Three germplasm lines *viz.*, ICGV 16679 (13.71 % leaf damage), ICGV 07222 (14.00 % leaf damage) and ICGV 93468 (14.25 % leaf damage) showed greater resistance than the resistant check, ICGV 86031 (15.04 % leaf damage) against leaf miner. The various morphological and biochemical characters were recorded and correlated with insect pest damage and incidence to know their role in imparting resistance/susceptibility. Resistance to various insect pests in germplasm lines was due to significantly higher trichome density on leaf lamina, higher phenol and tannin content.

2.2 Genetic variability in groundnut for yield and other traits

Manoharan *et al.* (1990) studied 21 F₁ hybrids of groundnut and recorded higher phenotypic coefficient of variance (PCV), genotypic coefficient of variance (GCV) and genetic advance for the characters plant height, pod number and pod yield but observed high heritability only for plant height.

A high magnitude of variability, heritability and genetic advance was observed for the length of secondary branches, 100-pod weight, sound mature kernel *per cent*

and pod yield per plant in 32 diverse groundnut genotypes grown at three environments differing in dates (Reddi *et al.*, 1991).

Senapathi and Roy (1991) evaluated 51 bunch groundnut genotypes for four seasons and found that pod yield and days to maturity reported a high variability and significant genotype $\times$ environment interactions.

Bansal *et al.* (1992) showed high genetic variation, heritability and genetic advance for pod and kernel yield and pod number in all three growth habits of groundnut.

Reddy and Gupta (1992) studied 46 genotypes of groundnut in three different environments and observed high genotypic coefficient of variation, heritability and genetic advance for days to 50 *per cent* flowering, plant height, number of secondary branches, mature pod number, kernel yield, pod yield and harvest index.

Maximum variability, high heritability coupled with high genetic advance were observed by Yadava *et al.* (1992) in three later generations of early maturity crosses of groundnuts for days to 50 *per cent* flowering, plant height, number of branches per plant, number of seeds per plant, seed yield per plant and 100-seed weight

Deshmukh *et al.* (1993) studied seven released varieties of groundnut for Vidharbha region of Maharashtra. He reported significant variation for pod yield, kernel yield and harvest index.

In 125 accessions and breeding lines of groundnut, a higher genotypic component of variability was observed for number of pods, number of seeds, pod weight per plant, 100-seed weight and shelling percentage (Pathirana, 1993).

Pod yield, 100-pod weight and 200-seed weight recorded higher PCV and GCV whereas height of main axis, 100-pod weight, 100-seed weight and harvest index recorded high heritability in 48 genotypes of groundnut (Reddy, 1994).

In 28 Spanish groundnut genotypes, Ganeshan and Sudhakar (1995) observed higher PCV and GCV for primary branches and moderate PCV and GCV for mature pods, height of main axis, and pod yield per plant. They also reported high heritability for days to 50 *per cent* flowering, primary branches, height of main axis and pod yield per plant. High genetic advance for primary branches and pod yield per plant was also recorded.

Sharma and Varshney (1995) studied 18 varieties of groundnut and observed wide of variability, heritability and genetic advance for pod yield per plant, biological range yield per plant and harvest index.

Moderate heritability was reported by Sumathi and Ramanathan (1995) for characters like plant height, number of primary branches, pod yield, number of mature pods, 100-pod weight, 100-kernel weight and shelling percentage in F₃ and F₄ generations of 33 lines of five crosses of groundnut.

Gowda *et al.* (1996) in a study involving F₄ generation for two crosses of groundnut reported higher variability for pod yield. However, variability was low for shelling *per cent*, mature kernel *per cent* and moderate for pod number and test weight.

In a study involving 63 three -way cross F₁, population of groundnut, GCV values for plant height, number of mature pods, 20-kernel weight and number of branches were highest. High heritability and genetic advance was observed for all the three traits indicating the action of additive gene effect in their expression (Varman and Raveendran, 1996).

Islam and Rasul (1998) observed highest genotypic coefficients of variation (GCV) for number of developed pods per plant (27.11) and seed yield (25.2) and also heritability in broad sense were high for days to 50 *per cent* flowering (96.25) and days to maturity (91.67). Highest genetic advance as a *per cent* of mean was observed for number of developed pods per plant and seed yield per plant (49.66 and 43.36, respectively).

High GCV, moderate heritability along with high genetic advance for plant height, haulm yield, biomass per plant and hundred kernel weight in groundnut germplasm was reported by Suryanarayana *et al.* (2001).

In another study involving 30 genotypes of groundnut, Venkataramana (2001) observed high GCV for kernel yield, oil yield and 100-kernel weight while sound mature kernel and oil content showed low to moderate GCV. However, high heritability and genetic advance was observed for 100-kernel weight, kernel yield and sound mature kernel *per cent*.

Nath and Alam (2002) subjected groundnut genotypes for estimation of variability, heritability and genetic advance and observed that, plant height, pods per plant, pod yield per plant, harvest index showed high PCV, heritability and genetic advance.

Makhan *et al.* (2003) observed higher PCV and GCV for plant height, number of mature pods, 100- pod weight and yield per plant in 67 lines of groundnut whereas days to maturity showed lowest PCV and GCV. High heritability and genetic advance were noticed for days to maturity, plant height and 100-pod weight.

Suneetha *et al.* (2004) in their study involving 23 genotypes of groundnut which included 5 lines, 3 testers and 15 F₁s derived out of line x tester mating system, high

heritability coupled with moderate genetic advance for days to 50 *per cent* flowering, height of main axis, total dry matter per plant, 100-pod weight, 100-kernel weight and pod yield was reported indicating the importance of additive and non-additive components of variance.

Kavani *et al.* (2004) in their study involving 15 genotypes of valencia groundnut, observed high GCV for pod yield per plant, kernel yield per plant and biomass yield per plant. Moderate GCV was recorded for harvest index and 100-kernel weight. These characters also registered high heritability coupled with high genetic advance.

Upadhyaya *et al.* (2005) found that heritability was high for shelling percentage, hundred seed weight, and moderate for days to first flowering and low for pod yield per plant.

Golakia *et al.* (2005) observed higher magnitude of PCV and GCV for pod yield, kernel yield and sound mature kernel percentage, except for shelling percentage and oil content in both runner and bunch habit groups for main stem height in Virginia runner types. High heritability coupled with high genetic advance was recorded for most of the characters studied, except for shelling percentage and oil content in 25 Virginia runner and 24 Spanish bunch groundnut genotypes.

In a study involving the effect of chemical mutagens on M₂ generation of groundnut, Veeramani *et al.* (2005) reported higher phenotypic coefficient of variation than the genotypic coefficient of variation for number of pods per plant, pod and kernel yield characters in all the treatments. Heritability and genetic advance as *per cent* mean for different characters were more in the treated populations.

Studies conducted by Praveen (2006) revealed that there was a positive association of pod and kernel yield with each other and other yield attributing traits like, number of pods per plant, number of mature pods per plant and sound mature kernel *per cent*.

John *et al.* (2007) observed significant differences among F₂ populations of six single crosses and parents for all characters. Plant height, number of secondary branches per plant, number of mature pods, pod yield per plant, kernel yield per plant, haulm yield per plant and harvest index showed high estimates of GCV and PCV. Heritability and GAM indicated the role of additive gene action in the inheritance of these traits.

Hariprasanna *et al.* (2008) reported predominance of additive gene action in expression of shelling out turn, 100-seed weight, while non additive gene action played an important role in the inheritance of seed yield.

Parameshwarappa and Kumar (2008) observed major role of non-additive gene action in the inheritance of pod yield, shelling *per cent*, number of pods and number of mature and immature pods in groundnut and concluded that shelling *per cent* and 100-kernel weight were found to be governed by both additive as well as non-additive gene action in different genetic backgrounds.

Khote *et al.* (2009) studied thirty exotic groundnut to assess their performance, genetic variability, heritability and genetic advance for yield and yield contributing characters. Higher phenotypic and genotypic coefficients of variations were observed for pods per plant, pod length, number of kernels per plant, kernel yield per plant, fodder yield per plant, harvest index and pod yield per plant. Characters like days to flowering, pod length, kernel length, 100-pod weight and dry matter per plant showed high heritability. The highest genetic advance as percentage of mean was recorded for kernel yield per plant, harvest index and pod yield per plant.

Eight genotypes of bunch groundnut with diverse origin were evaluated by Korat *et al.* (2009) to estimate variability, heritability and genetic advance. Traits like number of secondary branches per plant and number of aerial pegs per plant depicted high PCV and GCV and traits number of secondary branches per plant and number of aerial pegs per plant gave high heritability along with high genetic advance as *per cent* of mean indicating that, these were responsive to selection as they were controlled by additive gene action.

Fifty elite genotypes of Virginia bunch groundnut were evaluated for variability, heritability and genetic advance by Shinde *et al.* (2010). Analysis of variance revealed highly significant differences among the genotypes for all the characters studied except number of primary branches per plant. GCV and PCV estimates were higher for pod yield per plant, number of immature pods per plant, number of mature pods per plant and biological yield per plant. High heritability was associated with high genetic advance and high GCV for pod yield per plant and number of mature pods per plant only.

Raut *et al.* (2010) studied six crosses of F₂ population and nine parental lines for variability, heritability and genetic advance. The range of variation was maximum for plant height, shelling out-turn, oil content and pod yield per plant in most of the crosses. High values of GCV, PCV and genetic advance were observed for days to flowering, number of primary branches per plant, plant height, number of mature pods per plant, number of immature pods per plant, kernel yield per plant and pod yield per plant in most of the crosses.

A total of 34 groundnut genotypes were evaluated to estimate genetic variability, genetic parameters and correlation coefficient among different yield

components by Zaman *et al.* (2011). They observed that, kernel yield per hectare, kernel yield per plant, branches per plant, immature and mature nuts per plant, 100 kernel weight and plant height had highest coefficient of variation. Heritability was highest for the traits like kernel yield per plant, kernel yield per hectare, 100 kernel weight, immature and mature nuts per plant, branches per plant and 100 nut weight and in the case of genetic advance, all the characters except days to maturity and days to 50 *per cent* flowering gave high values.

John *et al.* (2012) conducted an experiment involving 28 F₂ populations which were evaluated for genetic parameters of 23 characters of morphological, physiological, yield and yield attributes. They reported that TPT-4 × ICGV-91114 recorded lowest mean value for days to maturity and highest mean values for number of well-filled and mature pods per plant, shelling *per cent* and 100 kernel weight. Number of secondary branches per plant gave high heritability and high GAM, days to 50 *per cent* flowering showed high heritability and moderate GAM. Leaf area index, number of mature pods per plant, dry haulms yield per plant and harvest index showed a moderate heritability and high GAM.

Genetic variation and association among nine characters were studied in eighteen selected groundnut genotypes by Narasimhulu *et al.* (2012). Analysis of variance revealed highly significant differences among the genotypes for all the characters studied. The PCV was generally higher than the GCV for all the characters but in some cases, the two values differed slightly. High heritability along with the GAM was high for pod yield per plant, kernel yield per plant, test weight, shelling percentage and three diseases, indicated the importance of additive gene action and the ample scope for improvement in these traits through simple selection.

Vishnuvardhan *et al.* (2012) conducted experiment on variability using twenty-eight F₂ populations. Moderate GCV registered for plant height at harvest, number of primary branches per plant, number of leaves per plant at harvest, number of mature pods per plant, kernel weight per plant indicating that additive and non-additive gene actions have a role in their inheritance and phenotypic selection would be effective to some extent. For days to 50 *per cent* flowering and days to maturity, GCV was low.

Fifteen groundnut genotypes (including check) obtained from ICRISAT, Hyderabad evaluated for qualitative parameters by Kumar *et al.* (2014). Moderate estimates of GCV were exhibited by kernel yield, days to 50 *per cent* flowering, seed yield per plant. Plant height, Seed index, Days to 50 *per cent* flowering, shelling percentage, pod yield per plant, kernel yield, seed yield per plant and pod yield (q/ha) exhibited high values for heritability (broad sense). Kernel yield exhibited high values for genetic advance as *per cent* of mean.

Maurya *et al.* (2014) conducted the experiment on variability studies using 15 groundnut genotypes. Based on *per se* performance, genotypes ICG 2772, ICG 2777 and ICG 3027 were found to be best for pod yield per plant. High to moderate estimates of GCV and PCV were exhibited by kernel yield, pod yield, pod yield per plant (g) and plant height (cm).

Including a mini core collection and some advanced breeding lines, Kukanur *et al.* (2014) conducted an experiment to estimate genetic variability, heritability and genetic advance as percentage of mean for yield and yield attributes. They found high (>20 %) PCV and GCV estimates for pods per plant, pod yield per plant, kernel yield per plant and test weight indicating the presence of variability. Plant height, primary branches per plant, pods per plant, kernel yield per plant, test weight, sound mature kernel percentage and pod yield per plant showed higher heritability and genetic advance as *per cent* of mean indicating presence of additive gene action and chance for selection.

The investigation was carried out with 58 Spanish bunch genotypes of peanut, by Patil *et al.* (2014). Analysis of variance revealed significant differences among the genotypes for all the characters studied. Maximum broad sense heritability was recorded for days to 50 *per cent* flowering followed by plant height and 100-kernels weight. In general, moderate to high heritability coupled with moderate to high genetic advance for days to 50 *per cent* flowering, plant height, 100-pods weight, 100-kernels weight, shelling percent and harvest index.

Yadlapalli (2014) had conducted an experiment at the Agricultural Research Station, Darsi, during *Kharif* 2009-10, 2010-11 and 2011-12. The trial was conducted in a randomized block design with three replications for estimation of genetic variability, genetic parameters and correlation coefficients among different yield components. Highly significant variations were observed among the genotypes for all the characters studied. The highest genetic coefficient of variation was observed for number of pods per plant followed by pod yield, 100 seed weight, number of branches per plant, plant height and days to 50 *per cent* flowering.

Thirumala Rao *et al.* (2014) had conducted experiment on extent of amenable genetic variability and association of important agronomic characters in a set of 50 groundnut genotypes. Analysis of variance revealed the existence of significant differences among genotypes for all the characters studied. The magnitude of PCV and GCV was moderate to high for number of pods per plant, plant height, kernel yield, dry pod yield, hundred kernel weight, and dry haulm yield.

Shukla and Rai (2014) conducted study to evaluate thirty groundnut genotypes for yield and quality traits. The components of variance revealed that the phenotypic

coefficient of variation (PCV) were higher than genotypic coefficient of variation (GCV) for all the characters studied indicating the role of environmental variance in the total variance. The magnitude of PCV and GCV was moderate to high for primary branches per plant at 40 DAS, pod yield, kernel yield, oil yield and oleic acid. High heritability coupled with high genetic advance was observed for oil yield.

Dewangan *et al.* (2015) evaluated 50 genotypes of groundnut were planted in randomized block design with K-6 as a check. High heritability was observed for plant height (99 %), seed index (94 %) and pod yield per plant (83 %). High value of genetic advance was observed for plant height (21.92), while moderate value of genetic advance was observed for seed index (18.07), followed by shelling percentage (12.67).

Gupta *et al.* (2015) conducted research on sixty diverse genotypes of Virginia groundnut during *Kharif* for variability parameters. The estimates of PCV and GCV were high for plant height, number of primary branches per plant, number of mature pods per plant, 100-pod weight, 100-kernel weight, biological yield per plant, kernel yield per plant and harvest index. High heritability coupled with high genetic advance expressed as percentage of mean was observed for 100-pod weight and 100-kernel weight.

Padmaja *et al.* (2015) conducted experiment to study the variability in F₂ population of JL 24 X ICG 11337 and JL 24 X ICG 13919 groundnut. Among these F₂ populations both the crosses showed high variability in the form of PCV, GCV heritability and GAM for mature pods per plant, total pods per plant, mature seeds per plant, haulm weight per plant, late leaf spot disease score at 75 DAS and pod yield per plant. High heritability coupled with moderate GAM for DAS 90 in both the crosses. The cross JL 24 X ICG 11337 recorded high heritability and genetic advance *as per cent* of mean for DS102.

Chavadhari *et al.* (2017) evaluated seventy groundnut genotypes for quantitative and yield parameters. A wide range of variation was observed for important yield components. High estimates of the genotypic coefficient of variation (GCV) were observed for kernel yield per plant followed by the number of branches per plant, harvest index and biological yield per plant. High heritability along with moderate genetic advance was observed for biological yield per plant, 100-kernel weight and harvest index indicating that these traits were mainly governed by additive gene action and responsive for further improvement of these traits.

Thirty-eight local collections of groundnut along with two checks namely TAG-24 and Kopergaon-3 were evaluated in RBD with three replications by Uikey *et al.* (2017). The results on correlation studies showed that dry pod yield per plant was significant and positively correlated with number of mature pods per plant at both

genotypic and phenotypic levels. Whereas, genotypic positive significant correlation of dry pod yield per plant was observed with number of primary branches per plant and mature kernels *per cent*.

Yusuf *et al.* (2017) carried out study to evaluate for quantitative parameters in groundnut genotypes (including local check). The analysis of variance revealed the prevalence of significant differences among the genotypes for all studied parameters. High to moderate estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were exhibited by all characters. High heritability was observed for 100 seed weight (91.2 %), above ground biomass per plant (90.3 %), number of branches per plant (90.2 %), plant height (89.4 %), number of mature pods per plant (86.8 %), number of seeds per pod (85.7 %), harvest index (83.7 %) and kernel yield per plot (79.7 %) accompanied by high genetic advance indicating the predominant role of additive gene action.

Hampannavar *et al.* (2018) evaluated 144 groundnut genotypes for the assessment of variability, heritability and genetic advance as *per cent* of mean by recording 13 characters. Among the studied characters, plant height (cm), number of primary branches per plant, number of mature and immature pods per plant, kernel yield per plant, hundred kernel weight (g), haulm yield per plant and dry pod yield per plant exhibited high GCV, PCV, heritability and genetic advance as the *per cent* of mean.

Mohammed *et al.* (2018) observed significant difference among the 38 genotypes for late leaf spot, 100-seed weight and dry pod yield and unshelled sample of 100 pods. Both 100-seed weight and unshelled sample of 100 pods showed highly significant negative correlation with late leaf spot at harvest. Genotypes susceptible to both late leaf spot (LLS) and groundnut rosette disease (GRD) recorded the lowest 100-seed weight. Nine genotypes showed resistance to both the diseases along with high yield potential.

Nandini *et al.* (2018) investigated 40 diverse genotypes of spanish bunch groundnut for variability studies. Moderate GCV and PCV values were observed for pod yield per plant, kernel yield per plant, number of mature pods per plant, dry haulms yield per plant, hundred kernel weight and hundred pod weight. Moderate heritability coupled with moderate genetic advance as *per cent* of mean was recorded by number of primary branches per plant, hundred seed weight, hundred kernel weight and dry haulms yield per plant.

Raza *et al.* (2018) evaluated 40 accessions to assess genetic variability for yield and its attributes. High heritability coupled with high genetic advance as *per cent* of mean was recorded by kernel yield per plant, hundred seed weight, pod yield per plant,

number of primary branches per plant, number of pods per plant, shelling *per cent*, harvest index, plant height and number of seeds per pod indicating that these characters are under additive genetic control.

Roy *et al.* (2018) conducted study to assess the genetic variability, heritability and genetic advance with 33 genotypes of groundnut. The characters studied were significantly different from each other. Moderate PCV and GCV with high heritability and high genetic advance as *per cent* of mean were observed for the traits viz., days to 50 *per cent* flowering, SPAD chlorophyll meter reading at 70 DAS, harvest index and 100 kernel weight. Kernel yield per plant recorded high PCV and moderate GCV with high heritability and genetic advance as *per cent* mean.

Kumar *et al.* (2019) carried out an experiment with 20 groundnut genotypes and evaluated 14 traits to find out the variability and correlation. ANOVA indicated required variation among the genotypes. The results showed that, days to 50 *per cent* flowering, number of pods per plant, 100 pod weight and sound mature kernel had high heritability coupled with high genetic advance. Primary branches per plant, pod yield and kernel yield had moderate GCV and PCV.

Vinithashri *et al.* (2019) carried out study to examine the variability of prominent yield and yield attributing traits in groundnut. High GCV, PCV values were recorded for the number of pods per plant, 100 pod weight, 100 kernel weight, shelling percent and number of mature kernels in the present study. This indicates the presence of ample variability for these traits. Most of the traits recorded high heritability and high GAM, which is a positive sign for least influence of environment on population and presence of additive gene action.

Kumari and Sasidharan (2020) carried out an experiment using fifty *Arachis* genotypes belonging to different botanical types. Analysis of variance indicated highly significant differences among genotypes for all the traits. In this study, high magnitude of genetic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) and high broad sense heritability was observed for 19 characters out of 28 characters. High genetic advance as percentage of mean was observed for 16 out of 28 characters, which indicate the necessity of utilising these traits for crop improvement in groundnut.

The investigation was carried out with 30 genotypes of peanut, pooled from ICRISAT by Shrotri *et al.* (2021). Analysis of variance revealed existence of quite substantial differences among the genotypes for all the characters examined. The genotypes viz., ICGV00189, ICGV0213 and ICGV00202 demonstrated high mean performance for pod yield and its element features viz., number of mature pods per plant, kernel yield per plant, hundred kernel weight and sound mature kernel. High heritability coupled with high genetic advance as *per cent* of mean was recorded by weight.

Fourteen genotypes of groundnut were obtained from ICRISAT, Pattancheru, Hyderabad and were evaluated by Veer and Kumar (2021) for quantitative parameters. Observations were recorded on twelve quantitative characters. Analysis of variance revealed the presence of significant amount of variability among the groundnut genotypes. Maximum genotypic coefficient of variation and phenotypic coefficient of variation was recorded for kernel yield (18.45 q/ha). All the characters showed maximum heritability for plant height (31.97 cm) and high genetic advance as percentage of mean was recorded for field emergence (235.5%). These characters may serve as an effective selection parameter during breeding programme for crop improvement in future.

Sridevi *et al.* (2022) conducted an experiment to study the genetic variability using thirty promising genotypes of groundnut. Kernel yield and its component characters were recorded. The magnitude of PCV and GCV values were higher for the characters *viz.*, number of branches, total biomass, 100 kernel weight, leaf area ratio and leaf area index. Total number of branches, total biomass and 100 kernel weight exhibited high heritability and high genetic advance as *per cent* of mean.

Genetic variability analysis was carried out for physiological, yield attributes and quality traits in 26 peanut genotypes by Deepthi *et al.* (2022). The study indicated the existence of a considerable amount of variability for every character. High heritability estimates were recorded for days to maturity, sound mature kernel *per cent*, days to 50 *per cent* flowering, dry haulms yield per plant, shelling *per cent*, kernel yield per plant, plant height, protein content, pod yield per plant, harvest index and a number of mature pods per plant stipulating that the effect of environment is least in the countenance of these characters. High heritability coupled with high genetic advance as *per cent* of mean (GAM) was recorded for dry haulms yield per plant, shelling *per cent*, kernel yield per plant, plant height, pod yield per plant, harvest index and the number of mature pods per plant indicating a preponderance of additive gene action.

Habite (2023) conducted experiment to evaluate genetic variability for 64 groundnut genotypes using 8x8 simple lattice design. Analysis of variance revealed that, there was highly significant differences among the 64 genotypes for all traits studied. Kernel yield showed the highest GCV and PCV values, while the lowest was seen in the shelling percentage. Harvest index, number of branches per plant, number of pods per plant, hundred seed weight, kernel yield, biomass yield and pod yield all showed moderate heritability and high genetic progress as a percentage of the mean.

2.3 Character association of yield and other traits in groundnut

Grain yield for any crop depends on many component characters that influence yield either jointly or singly and either directly or indirectly through other related

characters. Selection for yield on the basis of *per se* performance alone may not be effective as that based on the component characters associated with it, which is biometrically determined by correlation coefficient and path analysis. The correlation between characters may exist due to various reasons such as pleiotrophy, genetic linkage and association of loci or block of loci governing variability for different characters located on same chromosome. The extent of observed relationship between two characters is known as simple, total or phenotypic correlations.

Environmental correlation is the measure of environmental influence on the covariance between the two characters. An understanding of the nature and extent of association of the component characters with grain yield and amongst themselves is an essential prerequisite for formulating best breeding programme. The literature regarding correlation studies in groundnut have been reviewed and presented in the following paragraphs.

Vasanthi *et al.* (1998) reported that pod weight per plant showed significant positive correlation with sound matured kernel percentage and significant negative association with days to 50 *per cent* flowering. Shelling percentage showed significant positive association with sound matured kernel percentage, late leaf spot and rust severities but a significant negative association with days to maturity and haulm weight per plant. Late leaf spot and rust severities showed significant negative association with days to 50 *per cent* flowering, days to maturity and haulm weight per plant. Also reported the high heritability for 100-kernel weight, late leaf spot, rust, shelling *per cent*, sound mature kernel *per cent*, days to 50 *per cent* flowering and days to maturity but low for pod weight per plant. Genetic advance was high for 100 kernel weight, late leaf spot, rust and for others it was low.

Sah *et al.* (2000) evaluated 24 genotypes of mutant cultures of groundnut and reported that pod yield per plant was positively and significantly correlated with number of pods per plant, 100 seed weight, seed yield per plant, oil yield, whereas, it was negatively associated with shelling percentage. Oil yield was positively associated with number of pods per plant, 100-seed weight, seed yield per plant, number of primary branches per plant and number of seeds per pod.

Zilani Choudhury *et al.* (2000) in their study on 25 divergent genotypes of groundnut observed that pods per plant, 100 pod weights and kernel weight were positively and significantly correlated with pod yield per plant.

Cherian *et al.* (2000) in a study on path analysis for dry pod yield showed that days to 50 *per cent* flowering and plant height had positive indirect effect on dry pod yield through kernel yield per plant. Maximum direct effect was exhibited by kernel

yield per plant followed by plant height. Hence, emphasis should be given to these characters.

Mallikarjuna (2001) reported that days to maturity is strongly associated with pod yield per plant, positive significant correlation for days to maturity and days to initiation of flowering, negative significant correlation for oil content with pod yield per plant, positive significant correlation for days to maturity and days to initiation of flowering, negative significant correlation of oil content with pod yield per plant, test weight, shelling *per cent*, sound mature kernels, positive significant association of test weight and pod yield per plant.

Singh and Singh (2001) reported that number of primary branches had maximum positive direct effect on pod yield followed by 100-kernel weight, sound mature kernel percentage, harvest index and number of fruiting nodes. Main shoot height had largest negative direct effect on pod yield.

In 30 genotypes of groundnut, Venkataramana *et al.* (2001) noticed that pod yield had significant positive correlation with plant height, number of branches per plant, number of mature pods per plant, shelling *per cent*, sound mature kernel, 100-kernel weight, kernel yield per plant, harvest index and oil *per cent* at both genotypic and phenotypic levels. Further, pod yield showed negative association with days to 50 *per cent* flowering and maturity.

Yogendra *et al.* (2001) studied on path analysis at genotypic and phenotypic levels which indicated high positive direct effect of harvest index, number of primary branches, number of pods per plant, and shelling percentage at both the levels. The direct effect of days to 50 *per cent* flowering was negative at genotypic level and low at phenotypic level. The direct effect of percentage of sound mature kernel and 100-kernel weight at both genotypic and phenotypic levels was negative.

Makhan *et al.* (2003) studied 67 lines of groundnut and reported that plant height had significant positive correlation with leaf length, leaf width and number of mature pods, whereas yield per plant was positively related with days to maturity and number of mature pods.

Roy and Ojha (2003) noticed that number of pods per plant, 100- kernel weight, 100 pod weight, shelling *per cent* and days to 50 *per cent* flowering was positively and significantly correlated with yield per plant in 95 genotypes of groundnut.

Lakshmiddevamma *et al.* (2004) observed that pod yield possessed significant positive association with kernel yield, test weight, plant height, number of pegs, number of matured pods, test weight and oil yield at both genotypic and phenotypic levels.

Nagda and Joshi (2004) studied 80 F₁s and two checks of groundnut (TAG-24 and SB-XI) and reported that dry pod yield per plant had significant positive genotypic correlation with number of mature pods per plant, kernel yield per plant in both parents and hybrids.

Suneetha *et al.* (2004) reported positive and significant association of pod yield per plant with number of mature pods, total dry matter per plant and harvest index in 8 parents and their 15 F₁s of groundnut.

In a study involving 15 genotypes of Valencia groundnut, pod yield and kernel yield exhibited significant positive association with developed kernels per plant, 100-kernel weight and biomass yield by Suvarna (2004). Further, in their study reported that pod yield exerted significant and negative correlation with specific leaf area and positive correlation with 100-kernel weight and sound mature kernel percentage.

Golakia *et al.* (2005) observed significant and positive correlation of pod yield per plant with developed pods per plant, biomass yield per plant and harvest index, indicating that simultaneous selection for these characters might bring an improvement in pod yield.

In a study involving F₂ population of six single crosses and parents, plant height, number of secondary branches, pod yield had significant and positive correlation with number of secondary branches, number of mature pods, kernel yield, pod length, haulm weight and harvest index. Thus, indicated pod yield could be increased by improving these characters (John *et al.* 2005).

Kalmeshwar *et al.* (2006) reported that, pod yield per plant had positive association with number of pods per plant, shelling *per cent* and sound mature kernel *per cent* at three locations.

John *et al.* (2007) observed significant positive association of pod yield with number of mature pods per plant (0.541), SPAD chlorophyll meter reading (SCMR) (0.588), kernel yield per plant (0.981), pod width (0.682) and harvest index (0.832) in a study involving F₂ population of six single crosses and parents. Improvement in pod yield could be brought by selection for characters *viz.*, number of mature pods, kernel yield, pod width, SCMR and harvest index.

Mane *et al.* (2008) observed that, pod yield per plant had positive and significant correlation with *per cent* sound mature kernel, number of pegs per plant, number of pods per plant and shelling percentage. However, it showed negative and non-significant correlation with hundred kernel weight and days to 50 *per cent* flowering.

In the crosses TKG 19A X J-11 and J-11 X TGLPS 3, total number of pods, number of well filled pods, kernel weight, sound mature kernel and days to flowering had positive and significant association with pod yield and negative relationship of pod yield with damage of late leaf spot incidence, reduced yield and 100- kernel weight had positive association with shelling *per cent* and sound mature kernel *per cent* (Parameshwarappa and Kumar, 2008).

Sudhir *et al.*, (2008) observed that, pod yield per plant has positive significant association with mature pod per plant and kernel yield per plant and also found pod yield per plant has high direct effect on kernel yield and oil content in a study involving 64 genotypes of groundnut.

Korat *et al.* (2010) found that, the estimate of genotypic correlation coefficients in general higher than their corresponding phenotypic correlations indicating strong inherent association among the traits. Yield contributing characters like biological yield per plant, 100-kernel weight and harvest index had positive and significant association with pod yield per plant at phenotypic level. Days to maturity and pod yield per plant was found to have negative and significant association.

Meta and Monpara (2010) evaluated 50 elite genotypes of bunch groundnut, *Arachis hypogaea* L. to know the extent of association among the yield traits. Pod yield per plant was associated strongly and positively with kernel yield per plant, pods per plant, shelling outturn and oil content but its correlation was significantly negative with 100 pod weight, days to 50 *per cent* flowering and days to maturity.

Pradhan and Patra (2011) conducted an experiment including 460 genotypes of groundnut germplasm which were evaluated in four different seasons to study correlation among yield and yield attributing traits. They found positive association in all the seasons for unfilled pods per plant with number of branches per plant and hundred pods weight with hundred kernels weight.

A set of 100 Spanish bunch groundnut genotypes were evaluated for the estimation of correlation coefficient and path analysis for pod yield per plant and its component characters by Babariya and Dobariya (2012). They found that, the pod yield per plant was significantly and positively correlated with days to maturity, plant height, number of pods per plant, kernel yield per plant, number of mature pods per plant, 100 kernel weight, biological yield per plant and harvest index.

Shobha *et al.* (2012) conducted an experiment investigating correlation coefficients among nine yield and yield attributing traits with their path effects and they found that, kernel yield was significant and positively correlated with number of pods per plant, pod yield per plant, shelling percentage and hundred kernel weight. Kernel yield per plant was influenced by number of pods per plant and pod yield per plant.

They suggested that, number of pods per plant, pod yield per plant, hundred kernel weight and shelling percentage were the outstanding characters influencing kernel yield in groundnut.

Mukhtar *et al.* (2013) conducted irrigation trials using three groundnut genotypes during three dry seasons. Highest positive effect was showed by plant height followed by total dry matter and number of branches. Among all the growth characters studied, path analysis revealed plant height made the highest positive contribution to pod yield followed by total dry matter indicating that plant height is the most critical one for estimation of groundnut yield.

Zilani Choudary *et al.* (2013) conducted investigation to study character association in 27 groundnut genotypes. The association study among characters revealed that dry pod yield was positively and significantly correlated with number of pegs per plant, number of mature pods per plant and kernel yield per plant.

Alam (2014) carried out an experiment involving 45 groundnut genotypes and evaluated yield and yield contributing characters for correlation studies and reported that, pod yield showed significant positive association with secondary branches per plant, harvest index, 100 pod weight, 100 kernel weight, pod size, diseases incidence and canopy temperature.

Kumar *et al.* (2014) conducted an experiment involving 66 groundnut genotypes to assess correlation and path analysis for yield and yield attributing characteristics. Studies on correlation studies revealed that, kernel yield was significantly and positively associated with pod yield per plant, number of mature pods per plant, shelling percentage, harvest index, sound mature kernel percentage, specific leaf weight at 60 DAS, protein content and oil content and the path coefficient analysis revealed that pod yield per plant and shelling percentage had high positive direct effect on kernel yield.

Thirumala Rao *et al.* (2014) observed dry pod yield was significant positively correlated with kernel yield, number of pods per plant, hundred kernel weight and dry haulm yield.

Sabiel *et al.* (2014) studied twelve genotypes of groundnut to assess character association. Pod yield (Kg/ha) was highly significantly and positively correlated with hay yield (Kg/ha), shelling percentage and 100- seed weight, while non-significant and negatively correlated with days to 50 *per cent* flowering. Based on the results, the characters hay yield (Kg/ha), shelling percentage, 100- seed weight and days to 50 *per cent* flowering to be the important characters which would be used in selection for groundnut improvement.

Vange and Maga (2014) studied the breeding potentials of nine improved lines and one cultivated variety of groundnut and concluded that, grain yield correlated positively with all the traits. The path analysis implicated biological yield, failed pegs per plant, number of leaves per plant and basal stem diameter has influence on grain yield.

Bhargavi *et al.* (2015) conducted correlation and path analysis studies revealing that pod yield per plant has significant positive association with days to maturity, number of mature pods per plant, biological yield per plant, biological yield per hectare, harvest index, 100 kernel weight, kernel yield per plant, kernel yield per hectare, oil yield per hectare and pod yield per hectare and, the traits like 100 kernel weight, kernel yield per plant and biological yield per hectare exerted maximum positive direct effect on pod yield per plant.

Kiranmai *et al.* (2016) noticed strong positive association between pod yield per plant and kernel yield per plant, oil yield per plant. Pod yield was also correlated with 100- kernel weight, plant height and oil content. Inter correlation estimates for yield components revealed that plant height, 100-kernel weight, kernel yield per plant, oil yield per plant, late leaf spot severity, number of matured pods per plant, harvest index and plant height were significantly associated with one another and also with pod yield per plant.

Rao (2016) reported that, for all the characters studied there was a significant difference among the genotypes and significant positive correlation between dry pod yield and kernel yield, number of pods per plant, hundred kernel weight and SPAD chlorophyll meter reading (SCMR) was observed.

Fifty diverse genotypes of Virginia groundnut were evaluated for correlation by Vachhani (2016). The magnitudes of genotypic correlation coefficients were higher as compared to the corresponding phenotypic correlation coefficients. The pod yield per plant had highly significant and positive correlations at phenotypic level with days to 50 *per cent* flowering, number of mature pods per plant, kernel yield per plant, 100-kernel weight, biological yield per plant, shelling out-turn and harvest index.

Bhargavi *et al.* (2017) carried out a study of correlation analysis in ten genotypes of Virginia bunch groundnut for pod yield and its components. They found that, pod yield per plant showed significant positive association with number of mature pods per plant, biological yield per plant, biological yield per hectare, 100 kernel weight, oil yield per hectare, kernel yield per plant, kernel yield per hectare and pod yield per hectare.

Reddy *et al.* (2017) reported kernel yield per plant possessed significant positive association with pod yield per plant, mature pods per plant, 100-kernel weight,

Pods per plant, pegs per plant, harvest index and shelling percentage. Selection based on these characters will lead to simultaneous improvement in kernel yield in groundnut.

Hampannavar *et al.* (2018) conducted an experiment evaluating 144 groundnut genotypes. Results on correlation studies revealed that kernel yield per plant, mature pods per plant, sound mature kernel percentage and haulm yield per plant had significant positive correlation with dry pod yield per plant. Highest direct effect of kernel yield on dry pod yield had been noted by path coefficient analysis.

The thirty elite genotypes of groundnut were evaluated in randomized block design for character association by Kadam *et al.* (2018). The association between dry pod yield per plant and other quantitative characters showed significant and positive correlation with number of mature pods per plant, dry biomass, number of pegs per plant, fresh pod yield per plant, fresh biomass, fresh fodder yield per plant and immature pods per plant.

Mahesh *et al.* (2018) studied 144 groundnut genotypes for genetic advance as the *per cent* of mean. The phenotypic and genotypic correlation coefficient between kernel yield per plant, mature pods per plant, sound mature kernel and haulm yield per plant had significant positive correlation with dry pod yield per plant. The kernel yield had high direct effect on dry pod yield.

Nayak (2018) conducted study with 15 groundnut genotypes to estimate the correlation for yield and its components. Correlation studies revealed the simultaneous improvement of hundred pod weight, sound mature kernels and hundred kernel weight for improvement of the yield.

Correlation analysis was carried out for physiological, yield and yield contributing characters in 32 genotypes of groundnut by Saritha *et al.* (2018). Pod yield displayed significant positive association with number of primary branches per plant, number of secondary branches per plant, number of pegs per plant, number of mature pods per plant, number of immature pods per plant and harvest index.

Vaithiyalingan and Yogameenakshi (2018) undertaken the study to assess the nature and magnitude of association between pod yield and its components characters in large seeded groundnut genotypes. The trait sound mature kernel and 100 kernel weight had positive and significant association with pod yield per plant.

Jahanzaib *et al.* (2020) conducted study to estimate traits association in eleven groundnut advanced breeding lines together with check viz BARD-479, using randomized complete block design with three replications. Similarly, the trait of dry pods yield was in significant positive correlation with plant height, while was significant negatively correlated with number of branches.

Venkataravana *et al.* (2020) conducted study using three different F₂ populations of three cross combinations to study the extent of correlation of pod yield and its attributing characters. Phenotypic correlation coefficient analysis for yield and its attributing traits for all the three crosses were carried out and a significant positive association was found between kernel yield per plant and pod yield per plant.

Shrotri *et al.* (2021) conducted an experiment to evaluate the character association for pod yield and its components by employing thirty groundnut genotypes during *Kharif* 2020. The extent of genotypic coefficient of correlation found higher compared to the respective phenotypic coefficient of correlation. The pod yield per plant displays highly significant and positive correlation with the traits number of mature pods per plant, kernel yield per plant, hundred kernel weight and sound mature kernel at both phenotypic and genotypic level.

MATERIAL AND METHODS

III MATERIAL AND METHODS

The present investigation on ‘Genetic variability studies in Groundnut for tolerance to leaf miner (*Aproaerema modicella* D.)’ was carried out as two experiments to achieve the set objectives. The details of material used, and techniques adopted in the present study for recording of observations, analysis and interpretation of data are briefly presented in this chapter.

3.1. Experimental Material

The experimental material comprises 34 genotypes of groundnut including checks as presented in Table 1. The research was carried out during late *Kharif* 2022 at the Zonal Agricultural and Horticultural Research Station, Hiriya coming under central dry zone of Karnataka.

3.2. Experimental methods

3.2.1 Experimental layout

A field experiment was conducted during early *Rabi* 2022 at the Zonal Agricultural and Horticultural Research Station, Hiriya to screen 34 groundnut genotypes for leaf miner (*Aproaerema modicella* Deventer) tolerance under field condition. The genotypes were sown in a Randomized Complete Block Design (RCBD) with 2 replications each in control (with standard pest control measures to contain leaf miner infestation) and leaf miner stress (without any pest control measures to contain leaf miner infestation). The plot size was 2.00 m x 1.50 m (Plate 1). Details of location and date of sowing under present investigation is presented in Table 2.

3.2.2 Method of sampling and recording observations

Five plants in all the genotypes in each of the replications were used for taking the observations on below-cited characters. The average of observations recorded on the five plants was considered for statistical analysis. Similarly, plant morphological characters of each genotype were recorded by selecting a single or group of plants on all the characters at different stages of crop growth. The characters observed for eliciting the information are described below.

All the 34 genotypes were evaluated for leaf miner through visual screening method using 10-point scale for leaf miner (Table 3) given by Praveena *et al.* (2011) and the injury rating given by Rao and Wightman (1994) as depicted in Table 4. The scores were converted into *per cent* severity index (PDI). They were also evaluated for yield and yield attributing traits.

3.2.3.1 Days to 50 per cent flowering

The number of days taken from the date of sowing to 50 *per cent* of the plants to flower in the plot was recorded for each genotype.

Table 1. List of genotypes used in the present investigation

Sl. No.	Genotype	Pedigree	Source
1	TMV-2 (SC)	Mass selection from Gudhiatham bunch	ZAHRS, Hiriya
2	K-1812 (TC)	---	ARS, Kadiri
3	ICGV 181029	---	ZAHRS, Hiriya
4	HG 2023	TMV-2 x GPBD 4	ZAHRS, Hiriya
5	ICGV 15090	---	ZAHRS, Hiriya
6	HG-1-2021-9	TMV-2 x Dh 256	ZAHRS, Hiriya
7	HG-1-2021-16	TMV-2 x ICGV 16690	ZAHRS, Hiriya
8	HG-1-2021-5	TMV-2 x GPBD 4-1	ZAHRS, Hiriya
9	HG-1-2021-7	GPBD 4 x Dh 256	ZAHRS, Hiriya
10	HG-2-2021-9	Dh 256 x TMV-2	ZAHRS, Hiriya
11	Dh-232	GPBD-4 x TG 37A	UAS, Dharwad
12	KDG-128	(ICGV 87121 x ICGV 87853) x (ICGV	UAS, Raichur
13	Dh-256	R2001 -2 x GM4 - 3 -12	UAS, Dharwad
14	R-2001-2	ICGS-11 x ICG-4728	UAS, Dharwad
15	ICGV 16690	ICGV 06110 x Sun oleic 95 R	UAS, Raichur
16	Kadiri-9	Kadiri-4 x Vemana	ARS, Kadiri
17	R-8808	ICGS 11 x Chico	UAS, Raichur
18	R-2001-3	ICGS-11 x ICG-4728	UAS, Raichur
19	PBS 12200	---	RARS, Bikaner
20	DBG 4	MABC selection from TMV-2 x GPBD	UAS, Dharwad
21	TAG 24	TGS 2 x TGE1	UAS, Dharwad
22	Dh 257	ICGV07211 X ICGV 2381	UAS, Dharwad
23	JL 24	Selection from EC 94943	UAS, Dharwad
24	Dh 245	Mutant of GPBD - 4	UAS, Dharwad
25	G-2-52	Mutant of GPBD-4	UAS, Dharwad
26	GPBD 5	TG49 x GPBD-4	UAS, Dharwad
27	ICGV 06189	{(BIPn9 x ICGV95172) x [(ICGV88414 x USA63) x ICGV95172)]}	UAS, Dharwad
28	TGLPS 3	TAG-24 x TG-19	UAS, Dharwad
29	Dh-86	Dh-40 X Dh-8	UAS, Dharwad
30	GPBD 4	KRG1 x ICGV 86855	UAS, Dharwad
31	Dh 101	R 9214 X Dh 51-2	UAS, Dharwad
32	JSP 39	JSP-14 X JSSP-4	UAS, Dharwad
33	Dh 299	---	UAS, Dharwad
34	DBG 22	---	UAS, Dharwad

Note: SC- Susceptible Check; TC- Tolerant Check



Control plots (Leaf miner control measures taken)



Leaf miner infestation plots (Leaf miner control measures not taken)

Plate 1: Overview of Experimental plot

Table2: Details of location and date of sowing under present investigation

Sl. No.	Particulars	Details
1	Location	ZAHRS, Hiriya
2	Latitude	13.9570° N
3	Longitude	76.6457° E
4	Elevation	733.0 meters
5	Spacing	30 × 10 cm
6	Date of sowing	12/09/2022

Table 2.1: Weather data prevailing during the crop season

Month	Max	Min	R H		B S S	W S	Normal Rainfall	Rainfall (mm)	Rainy days	EVP
Sept	29.4	20.6	82	67	5.5	1.44	134.2	194.6	10	3.8
October	28.5	20.1	83.3	70.2	5.7	0.80	128.4	107.8	6	3.2
November	28.0	16.9	84.5	67.5	6.3	0.746	44.5	48.8	3	3.3
December	28.2	14.8	79.9	52.7	6.6	0.85	14.4	36	2	3.03
January	29.5	10.7	77.04	56.62	8.7	0.69	6.7	0	0	3.00
Total							629.7	1161.0	59	

Table 3: Leaf miner scoring

Leaflet damage (%)	Score (A)	Foliage damage (%)	Score (B)
0	1	0	1
10-20	2	10-20	2
21-30	3	21-30	3
31-40	4	31-40	4
41-50	5	41-50	5
51-60	6	51-60	6
61-70	7	61-70	7
71-80	8	71-80	8
81-90	9	81-90	9
91-100	10	91-100	10

Table 4: Injury rating scale for leaf miner

Sl. No	Foliage damage (%)	Resistance reaction
1	0	Highly tolerant
2	1-20	Tolerant
3	21-40	Moderately tolerant
4	41-60	Susceptible
5	61-100	Highly susceptible

3.2.3.2 Days to physiological maturity

The number of days taken from the date of sowing to physiological maturity of the plants was recorded for each genotype.

3.2.3.3 Plant height (cm)

The plant height was recorded as the height of the main axis from ground level to apical leaflet in five plants in each genotype.

3.2.3.4 Number of primary branches per plant

The total number of primary branches borne on the main axis in five plants in each genotype was counted.

3.2.3.5 Number of mature pods per plant

Total number of mature pods produced in five plants in each genotype was counted together.

3.2.3.6 Pod yield per plant (g)

The weight of total pods per plant obtained after optimum drying of the plants were recorded.

3.2.3.7 Kernel yield per plant (g)

The weight of the total kernels obtained from pods per plant was recorded.

3.2.3.8 Pod yield (Kg/ha)

The weight of total pods per plot obtained after optimum drying of the plants were recorded and then expressed as Kg/ha.

3.2.3.9 Kernel yield (Kg/ha)

After shelling, weight of the total kernels obtained from pods per plot was recorded and expressed as Kg/ha.

3.2.3.10 Shelling Percentage (%)

A random sample of pods from each genotype was drawn and its weight was recorded. Then, the quantity of kernels recovered after shelling the same sample of pods was recorded. The shelling percentage was calculated with the help of following formula:

$$\text{Shelling percentage (\%)} = \frac{\text{Kernel yield}}{\text{Pod yield}} \times 100$$

3.2.3.11 Test weight (g)

A random sample of 100 filled seeds (avoiding shrivelled and broken ones) was drawn and its weight was recorded in grams to get 100 kernel weight.

3.2.3.12 Haulm yield per plant (g)

The weight of left over plant parts (haulm) after picking all the pods from the plant was recorded.

3.2.3.13 Pest scoring for leaf miner

Visual observations were made on *per cent* foliage damage (0-100 %) due to leaf miner infestation at four stages *i.e.*, 30, 60, 90 days after sowing and also at maturity by following the standard scale 1-10 for categorization of genotypes. The severity index was then calculated by using mean damage scoring of leaflets and foliage damage as given by Anonymous (1986). The symptoms of leaf miner infestation in groundnut has been depicted in Plate 2.

3.2.4 Agronomic Practices

Season: Early Rabi

Seed rate: 125 Kg/ha

Spacing: 30×10 cm

Fertilizer Application: Applied NPK fertilizers as per soil test recommendation and FYM 10 t/ha.

N	P	K	Sulphur sludge
25	50	75 kg/ha	60 Kg/ha

N and K in three splits *viz.*, 50 % N & K as basal + 25 % N and K at 20 DAS + 25 % N and K at 45 DAS is recommended.

Irrigation: Peg formation stage is critical stage, supplemental irrigation is given and the interval between irrigation ranges from 8-12 days.

Weed control: For controlling weeds, and also to keep the soil in a friable condition, the crop should generally receive a hand-weeding and one or two hoeing. No interculture would be done after the pegs (about 55 days) have commenced going underground.

Harvesting: Groundnuts mature from 90-130 days depending on the varieties. Mature nuts should be firm and dry and brown on the outside. The inside of the pods should be grey and produce a rattling sound when shaken.

Control measures: Spraying of karate (Lambda cyhalothrin) at 35 and 55 days after sowing for control plots.



Larval mines



Webbing



Blister like mines



Burnt-up appearance

Plate 2: Symptoms of Leaf miner infestation in Groundnut

3.3 Statistical analysis

The mean values of five randomly selected plants for recording twelve different characters were used for statistical analysis. The experimental data on both growth and yield parameters were compiled and subjected to the following statistical analysis. Analysis was carried out by using R software.

3.3.1 Analysis of variance (ANOVA)

The data of mean value for all the characters were analysed for their variance following Randomized Complete Block Design outlined by Cochran and Cox (1957). Analysis was done using R software.

Source of variation	df	SS	MSS	F Ratio
Replication	(r-1)	SSr	$SSr/(r-1) = MSSR$	$MSSR/MSSE$
Genotype	(t-1)	SSg	$SSg/(t-1) = MSSG$	$MSSG/MSSE$
Error	(r-1) (t-1)	SSe	$SSe/(t-1) (r-1) = MSSE$	
Total	(rt-1)	SS _t		

Where,

r = number of replications

df = degrees of freedom

t = number of genotypes

SSr = replication sum of squares

MSSR = replication mean sum of squares

SSg = genotypic sum of squares

MSSG = genotype mean sum of squares

SSe = error sum of squares (SS_t-SSg-SSr)

The Sum of squares can be obtained as follows,

Total sum of squares (TSS) = $\Sigma (\text{No. of observations})^2 - CF$

Where,

CF = Correction factor

Genotype sum of squares (SSG) = $\Sigma (T_i)^2/n - CF$

Where,

n = Number of replications

Replication sum of squares (SSR) = $\Sigma (R_j)^2/s - CF$

Where,

s = Number of genotypes

Error sum of squares (SSE) = TSS-SSG-SSR

3.6.1.1 Mean

Mean is the sum of all observations in a sample divided by the number of observations (n).

$$\bar{X} = \frac{[\sum_{i=1}^n X_i]}{n}$$

Where,

x_i = i^{th} observation of a population

n = number of observations

3.3.2 Range

Range is the minimum and maximum values of the observations in a sample of a genotype.

3.3.3 Standard error

It is the measure of uncontrolled variation present in a sample which is estimated by dividing the standard deviation (SD) by the square root of number of observations (n) in the sample and is denoted by SE.

$$SE = \frac{SD}{\sqrt{n}}$$

3.3.4 Standard error difference between two means (SEd.m)

It is calculated with the help of error mean sum of square from ANOVA table.

$$SEd.m = \sqrt{\frac{2MSSE}{r}}$$

Where,

r = number of replications

MSSE = error mean sum of square

3.3.5 Critical difference (CD)

It is calculated to judge whether the difference between two particular treatments was significant or not.

$$\text{CD at 1 \% or 5 \% probability level} = \sqrt{\frac{2\text{MSSE}}{r}} \times t$$

Where,

r = number of replications

MSSE = error mean sum of square

t = table t value at 5 % or 1 % probability level for error degrees of freedom.

3.3.6 Coefficient of variation (CV)

It is the ratio of standard deviation of a sample to its mean and expressed in percentage.

$$\text{CV (\%)} = \frac{\text{Standard deviation}}{\text{mean}} \times 100$$

3.3.7 Variance

The mean of squared deviations of individual values from their mean is called variance.

$$\text{Variance} = \frac{\sum (X - \bar{X})^2}{n}$$

3.3.8. Estimation of genetic parameters

The genotypic and phenotypic variances were estimated using the formula given by Weber and Moorthy (1952).

$$\text{Genotypic variance } (\sigma^2_g) = \frac{\text{MSS (genotype)} - \text{MSS (error)}}{\text{Number of replications}}$$

$$\text{Phenotypic variance } (\sigma^2_p) = \sigma^2_g + \text{MSS (error)}$$

3.3.9 Coefficient of variability

The coefficient of variability both at phenotypic and genotypic levels for all the characters was computed by applying the formula, as suggested by Burton and De Vane (1953).

3.3.9.1 Phenotypic coefficient of variation (PCV)

$$\text{PCV} = \frac{\sigma_p}{\bar{X}} \times 100$$

3.3.9.2 Genotypic coefficient of variation (GCV)

$$\text{GCV} = \frac{\sigma_g}{\bar{X}} \times 100$$

Where,

$\bar{X}$ = grand mean of the character

σ_p = phenotypic standard deviation

σ_g = genotypic standard deviation

Categorization of the range of variability as proposed by Sivasubramanian and Madhavamenon (1973) is as follows.

Scale	Value of GCV and PCV (%)
Low	Less than 10
Moderate	10 – 20
High	More than 20

3.3.4 Heritability and Genetic advance

3.3.4.1 Heritability

Hanson *et al.* (1956) defined heritability in broad sense as the ratio of genotypic variance to the total variance in the non-segregating populations. Heritability was calculated by the formula given by Lush (1949).

$$H = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

Where,

H = Heritability in broad sense (h^2_{bs})

σ_g^2 = Genotypic variance

σ_p^2 = Phenotypic variance

As suggested by Johnson *et al.* (1955), h^2_{bs} estimates were categorized as follows:

Scale	Values of heritability in broad sense (%)
Low	Less than 30
Moderate	30 – 60
High	More than 60

3.3.4.2 Genetic Advance (Expected)

Genetic advance denotes the improvement in the genotypic value of the new population over the base population, and it is estimated by the following formula suggested by Lush (1949).

$$\text{Genetic Advance (Predicted)} = H \times \sqrt{\sigma_p^2} \times K$$

Where,

H = Heritability coefficient

$\sqrt{\sigma_p^2}$ = Phenotypic standard deviation

K = Selection differential in the standard units which is 2.06 at 5 *per cent* selection intensity

3.3.4.3 Genetic advance as per cent of mean (GAM)

Genetic advance as *per cent* of mean was calculated by following formula.

$$\text{GAM} = \frac{\text{GA}}{\bar{X}} \times 100$$

Where,

GA = Expected genetic advance

$\bar{X}$ = General mean of the character in the population

The range of GAM was classified as suggested by Johnson *et al.* (1955).

Scales	Value of Genetic Advance (%)
Low	Less than 10
Moderate	10 – 20
High	More than 20

3.3.5 Correlation coefficient analysis

The concept of correlation was first given by Galton (1889), which was further elaborated by Fisher (1919) to initiate an effective selection program aimed at genetic enhancement of the economic yield of the crop plants.

The correlation coefficients were calculated to determine the degree of association of characters with yield and yield components. The phenotypic correlation coefficient helps to determine the selection index, whereas, the genotypic correlation coefficient provides a close measure of association between characters, which may be useful for the overall yield improvement.

Genotypic correlation is the inherent association between the two variables, and it may be either due to the pleiotropic action of genes or linkage. If the correlation

between yield and a character is due to the direct effect of the character, it reflects a true relationship between them, and selection can be practiced for such characters. However, if the correlation is mainly due to the indirect effect of the character through another component trait, the breeder has to select for the trait through which the indirect effect is expected. An excellent yield response is obtained when indirect selection is practiced for the character having high heritability and positive correlation with yield. Both genotypic and phenotypic coefficients of correlation between two characters were determined by using the variance and covariance components, as suggested by Al-Jibouri *et al.* (1958).

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

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

Where,

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

Cov_g and Cov_p are the genotypic and phenotypic covariances, respectively.

σ_g^2 and σ_p^2 are the genotypic and phenotypic variances, respectively.

x and y are the two traits for which correlation coefficient is estimated.

3.3.5.1 Test of significance

For testing the significance of correlation coefficients, the estimated values were compared with the table value (Fisher and Yates, 1938) at n-2 degrees of freedom (where n denotes the number of genotypes tested) at 5 % and 1 % level of significance).

The range of correlation coefficients was classified as suggested by Searle (1965).

Scales	Value of Correlation Coefficients
Very strong	More than 0.65
ssModerately strong	0.50 to 0.64
Moderately weak	0.30 to 0.49
Very weak	Less than 0.30

3.3.6. Arcsine transformation

Arcsine transformation is used for data obtained from counts and data expressed as decimal fractions or percentages. For the leaf miner *per cent* foliage damage transformation is done. It was calculated by using following formula.

$$\text{Transformation} = \frac{\text{ASIN}(\text{SQRT}(A1/100)) \times 180}{3.14159}$$

Where,

ASIN = Arcsine

SQRT = square root

A1 = Percentage data

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

Pest and diseases are a major impediment to agricultural output around the world, and it poses a significant threat to food security. Plant breeding success is determined by the amount of variability in a crop. Groundnut breeding aims to utilize genetic variability and association among characters to yield for developing a desired genotype. As a result, the current study on groundnut was conducted to identify the leaf miner tolerant genotypes. The data were analyzed statistically to determine genetic variability parameters and correlations between the various traits under investigation.

The findings of this investigation are presented under the following headings.

- 4.1 Comparative mean performance of groundnut genotypes for tolerance to leaf miner
- 4.2 Comparative mean performance of groundnut genotypes for growth and yield traits under control and leaf miner infestation
- 4.3 Analysis of variance for yield and yield attributes
- 4.4 Genetic variability parameters for yield and yield attributes in groundnut under control and stress condition
- 4.5 Phenotypic correlation analysis under control and leaf miner infestation (stress condition)

4.1 Comparative mean performance of groundnut genotypes for foliage damage due to leaf miner infestation

4.1.1 Per cent difference in the mean foliage damage at different growth stages

Under leaf miner infested stress and control conditions, *per cent* foliage damage in 34 genotypes at 4 intervals/growth stages (30, 60, 90 DAS and maturity) was compared to assess the response of each genotype to leaf miner infestation. At all the 4 growth stages/intervals, significant differences in the level of leaf damage due to leaf miner infestation in terms of change in *per cent* mean has been depicted in Table 5.

4.1.1.1 Foliage damage at 30 days after sowing

Least increase in the foliage damage at 30 DAS under leaf miner infested stress as against control was noticed in the case of Dh-86 and ICGV 16690 with a mean increase of 6.46 (64.72 %). Meanwhile, the genotypes TMV-2, HG-2021-9, GPBD-5, DBG-22 and GPBD-4 have recorded maximum increase in the mean foliage damage of 18.44 (226.75 %) under leaf miner stress compared to the control condition.

4.1.1.2 Foliage damage at 60 days after sowing

Least increase in the foliage damage at 60 DAS under leaf miner infested stress condition as against control was noticed in the case of K-1812 with an increase in the mean foliage damage of 8.47 (84.83 %) followed by R-2001-3 (114.73 %). Meanwhile,

Table 5: Comparison of leaf miner damage under control and leaf miner infestation stress in groundnut genotypes

Sl. No.	Genotype	Foliage damage at 30 DAS (%)			
		Control	Stress	Increase in the mean foliage damage	<i>Per cent</i> increase in the mean foliage damage
1	TMV-2	8.13 (2.00)	26.58 (20.00)	18.44	226.75
2	K-1812	9.98 (3.00)	17.47 (9.00)	7.49	75.03
3	ICGV 181029	8.13 (2.00)	25.86 (19.00)	17.72	217.85
4	HG 2023	8.13 (2.00)	17.47 (9.00)	9.33	114.73
5	ICGV15090	9.98 (3.00)	18.44 (10.00)	8.47	84.83
6	HG-1-2021-9	9.98 (3.00)	25.12 (18.00)	15.14	151.69
7	HG-2021-16	9.98 (3.00)	17.47 (9.00)	7.49	75.03
8	HG-2021-5	8.13 (2.00)	16.44 (8.00)	8.30	102.09
9	HG-2021-7	9.98 (3.00)	17.47 (9.00)	7.49	75.03
10	HG-2021-9	8.13 (2.00)	26.58 (20.00)	18.44	226.75
11	Dh-232	9.98 (3.00)	17.47 (9.00)	7.49	75.03
12	KDG-128	8.13 (2.00)	16.44 (8.00)	8.30	102.09
13	Dh-256	9.98 (3.00)	22.80 (15.00)	12.82	128.45
14	R-2001-2	8.13 (2.00)	16.44 (8.00)	8.30	102.09
15	ICGV 16690	9.98 (3.00)	16.44 (8.00)	6.46	64.72
16	Kadiri-9	9.98 (3.00)	17.47 (9.00)	7.49	75.03
17	R-8808	8.13 (2.00)	17.47 (9.00)	9.33	114.73
18	R-2001-3	8.13 (2.00)	14.19 (6.00)	6.05	74.40
19	PBS-12200	9.98 (3.00)	17.47 (9.00)	7.49	75.03
20	DBG-4	9.98 (3.00)	17.47 (9.00)	7.49	75.03
21	TAG24	8.13 (2.00)	25.12 (18.00)	16.98	208.78
22	Dh-257	8.13 (2.00)	17.47 (9.00)	9.33	114.73
23	JL-24	9.98 (3.00)	18.44 (10.00)	8.47	84.83
24	Dh-245	8.13 (2.00)	25.86 (19.00)	17.72	217.85
25	G-2-52	9.98 (3.00)	18.44 (10.00)	8.47	84.83
26	GPBD-5	8.13 (2.00)	26.58 (20.00)	18.44	226.75
27	ICGV06189	9.98 (3.00)	17.47 (9.00)	7.49	75.03
28	TGLPS-3	8.13 (2.00)	15.35 (7.00)	7.22	88.70
29	Dh-86	9.98 (3.00)	16.44 (8.00)	6.46	64.72
30	GPBD-4	8.13 (2.00)	26.58 (20.00)	18.44	226.75
31	Dh-101	9.98 (3.00)	25.12 (18.00)	15.14	151.69
32	JSP-39	8.13 (2.00)	18.44 (10.00)	10.31	126.75
33	Dh-299	9.98 (3.00)	18.44 (10.00)	8.47	84.83
34	DBG-22	8.13 (2.00)	26.58 (20.00)	18.44	226.75

Note: values in the parenthesis are *per cent* foliage damage and values outside parenthesis are arcsine transformed values

Continued....

Sl. No.	Genotype	Foliage damage at 60 DAS (%)			
		Control	Stress	Increase in the mean foliage damage	Per cent increase in the mean foliage damage
1	TMV-2	8.13 (2.00)	32.60 (29.00)	24.47	300.77
2	K-1812	9.98 (3.00)	18.44 (10.00)	8.47	84.83
3	ICGV 181029	8.13 (2.00)	31.96 (28.00)	23.83	292.96
4	HG 2023	8.13 (2.00)	22.80 (15.00)	14.66	180.27
5	ICGV15090	9.98 (3.00)	31.96 (28.00)	21.98	220.31
6	HG-1-2021-9	9.98 (3.00)	34.47 (32.00)	24.49	245.39
7	HG-2021-16	9.98 (3.00)	33.23 (30.00)	23.25	232.97
8	HG-2021-5	8.13 (2.00)	31.96 (28.00)	23.83	292.96
9	HG-2021-7	9.98 (3.00)	26.58 (20.00)	16.60	166.34
10	HG-2021-9	8.13 (2.00)	26.58 (20.00)	18.44	226.75
11	Dh-232	9.98 (3.00)	27.99 (22.00)	18.01	180.44
12	KDG-128	8.13 (2.00)	23.59 (16.00)	15.46	190.01
13	Dh-256	9.98 (3.00)	26.58 (20.00)	16.60	166.34
14	R-2001-2	8.13 (2.00)	30.02 (25.00)	21.88	269.00
15	ICGV 16690	9.98 (3.00)	33.23 (30.00)	23.25	232.97
16	Kadiri-9	9.98 (3.00)	26.58 (20.00)	16.60	166.34
17	R-8808	8.13 (2.00)	25.12 (18.00)	16.98	208.78
18	R-2001-3	8.13 (2.00)	17.47 (9.00)	9.33	114.73
19	PBS-12200	9.98 (3.00)	25.12 (18.00)	15.14	151.69
20	DBG-4	9.98 (3.00)	33.23(30.00)	23.25	232.97
21	TAG24	8.13 (2.00)	30.02 (25.00)	21.88	269.00
22	Dh-257	8.13 (2.00)	26.58 (20.00)	18.44	226.75
23	JL-24	9.98 (3.00)	33.23 (30.00)	23.25	232.97
24	Dh-245	8.13 (2.00)	31.32 (27.00)	23.19	285.07
25	G-2-52	9.98 (3.00)	22.80 (15.00)	12.82	128.45
26	GPBD-5	8.13 (2.00)	25.12 (18.00)	16.98	208.78
27	ICGV 06189	9.98 (3.00)	26.58 (20.00)	16.60	166.34
28	TGLPS-3	8.13 (2.00)	31.96 (28.00)	23.83	292.96
29	Dh-86	9.98 (3.00)	26.58 (20.00)	16.60	166.34
30	GPBD-4	8.13 (2.00)	30.02 (25.00)	21.88	269.00
31	Dh-101	9.98 (3.00)	38.08 (38.00)	28.10	281.55
32	JSP-39	8.13 (2.00)	26.58 (20.00)	18.44	226.75
33	Dh-299	9.98 (3.00)	25.12 (18.00)	15.14	151.69
34	DBG-22	9.98 (3.00)	33.23 (30.00)	23.25	232.97

Continued....

Sl. No.	Genotype	Foliage damage at 90 DAS (%)			
		Control	Stress	Increase in the mean foliage damage	Per cent increase in the mean foliage damage
1	TMV-2	9.98 (3.00)	45.02 (50.00)	35.04	351.16
2	K-1812	11.54 (4.00)	22.80 (15.00)	11.26	97.51
3	ICGV 181029	9.98 (3.00)	39.25 (40.00)	29.27	293.33
4	HG 2023	8.13 (2.00)	25.86 (19.00)	17.72	217.85
5	ICGV15090	9.98 (3.00)	43.88 (48.00)	33.90	339.67
6	HG-1-2021-9	11.54 (4.00)	38.08 (38.00)	26.53	229.87
7	HG-2021-16	9.98 (3.00)	36.29 (35.00)	26.31	263.65
8	HG-2021-5	8.13 (2.00)	35.08 (33.00)	26.95	331.26
9	HG-2021-7	9.98 (3.00)	42.15 (45.00)	32.17	322.39
10	HG-2021-9	8.13 (2.00)	33.23 (30.00)	25.09	308.49
11	Dh-232	9.98 (3.00)	31.96 (28.00)	21.98	220.31
12	KDG-128	8.13 (2.00)	30.02 (25.00)	21.88	269.00
13	Dh-256	9.98 (3.00)	33.23 (30.00)	23.25	232.97
14	R-2001-2	11.54 (4.00)	38.08 (38.00)	26.53	229.87
15	ICGV 16690	9.98 (3.00)	39.25 (40.00)	29.27	293.33
16	Kadiri-9	9.98 (3.00)	29.35 (24.00)	19.37	194.10
17	R-8808	8.13 (2.00)	34.47 (32.00)	26.33	323.73
18	R-2001-3	9.98 (3.00)	20.28 (12.00)	10.30	103.20
19	PBS-12200	9.98 (3.00)	33.23 (30.00)	23.25	232.97
20	DBG-4	12.93(5.00)	42.15 (45.00)	29.22	226.06
21	TAG24	9.98(3.00)	38.08 (38.00)	28.10	281.55
22	Dh-257	8.13(2.00)	33.23 (30.00)	25.09	308.49
23	JL-24	9.98(3.00)	39.25 (40.00)	29.27	293.33
24	Dh-245	8.13(2.00)	34.47 (32.00)	26.33	323.73
25	G-2-52	9.98 (3.00)	42.15 (45.00)	32.17	322.39
26	GPBD-5	11.54 (4.00)	36.89 (36.00)	25.35	219.58
27	ICGV06189	12.93 (5.00)	43.88 (48.00)	30.95	239.40
28	TGLPS-3	9.98 (3.00)	38.08 (38.00)	28.10	281.55
29	Dh-86	9.98 (3.00)	30.02 (25.00)	20.04	200.78
30	GPBD-4	9.98 (3.00)	36.29 (35.00)	26.31	263.65
31	Dh-101	9.98 (3.00)	46.74 (53.00)	36.76	368.41
32	JSP-39	8.13 (2.00)	30.02 (25.00)	21.88	269.00
33	Dh-299	9.98 (3.00)	31.96 (28.00)	21.98	220.31
34	DBG-22	9.98 (3.00)	39.25 (40.00)	29.27	293.33

Continued....

Sl. No.	Genotype	Foliage damage a maturity (%)			
		Control	Stress	Increase in the mean foliage damage	Per cent increase in the mean foliage damage
1	TMV-2	9.98 (3.00)	71.60 (90.00)	61.62	617.50
2	K-1812	11.54 (4.00)	25.86 (19.00)	14.31	123.99
3	ICGV 181029	8.13 (2.00)	43.88 (48.00)	35.74	439.40
4	HG 2023	8.13 (2.00)	38.08 (38.00)	29.94	368.10
5	ICGV15090	9.98 (3.00)	50.21 (59.00)	40.23	403.15
6	HG-1-2021-9	9.98 (3.00)	50.79 (60.00)	40.81	409.00
7	HG-2021-16	9.98 (3.00)	55.58 (68.00)	45.60	456.94
8	HG-2021-5	8.13 (2.00)	50.79 (60.00)	42.66	524.45
9	HG-2021-7	9.98 (3.00)	47.89 (55.00)	37.91	379.93
10	HG-2021-9	8.13 (2.00)	42.15(45.00)	34.02	418.20
11	Dh-232	9.98 (3.00)	45.02 (50.00)	35.04	351.16
12	KDG-128	8.13 (2.00)	36.29 (35.00)	28.16	346.13
13	Dh-256	9.98 (3.00)	39.25 (40.00)	29.27	293.33
14	R-2001-2	11.54 (4.00)	47.32 (54.00)	35.78	309.94
15	ICGV 16690	9.98 (3.00)	53.76 (65.00)	43.78	438.68
16	Kadiri-9	9.98 (3.00)	33.23 (30.00)	23.25	232.97
17	R-8808	8.13 (2.00)	38.08 (38.00)	29.94	368.10
18	R-2001-3	11.54 (4.00)	26.58 (19.00)	15.04	130.26
19	PBS-12200	9.98 (3.00)	42.15 (45.00)	32.17	322.39
20	DBG-4	9.98 (3.00)	53.76 (65.00)	43.78	438.68
21	TAG24	9.98 (3.00)	49.05 (57.00)	39.07	391.51
22	Dh-257	8.13 (2.00)	45.02 (50.00)	36.89	453.50
23	JL-24	9.98 (3.00)	63.47 (80.00)	53.49	535.99
24	Dh-245	8.13 (2.00)	45.02 (50.00)	36.89	453.50
25	G-2-52	9.98 (3.00)	53.76 (65.00)	43.78	438.68
26	GPBD-5	12.93 (5.00)	56.82 (70.00)	43.89	339.51
27	ICGV06189	12.93 (5.00)	55.58 (68.00)	42.65	329.92
28	TGLPS-3	11.54 (4.00)	47.89 (55.00)	36.35	314.92
29	Dh-86	9.98 (3.00)	47.89 (55.00)	37.91	379.93
30	GPBD-4	9.98 (3.00)	50.79 (60.00)	40.81	409.00
31	Dh-101	9.98 (3.00)	60.03 (75.00)	50.05	501.55
32	JSP-39	8.13 (2.00)	42.15 (45.00)	34.02	418.20
33	Dh-299	9.98 (3.00)	43.88 (48.00)	33.90	339.67
34	DBG-22	11.54 (4.00)	45.02 (50.00)	33.48	290.05

the genotype TMV-2 has recorded maximum increase in the mean foliage damage of 24.47 (300.77 %) under leaf miner stress compared to the control condition.

4.1.1.3 Foliage damage at 90 days after sowing

The genotype, Dh-101 has recorded a maximum increase in the mean foliage damage under leaf miner infestation stress (368.41 %) followed by TMV-2 (351.16 %) compared to control. However, the genotype K-1812 registered least increase under stress compared to control (97.51 %) followed by R-2001-3 (103.20 %).

4.1.1.4 Foliage damage at maturity

All the test genotypes exhibited increased *per cent* foliage damage under leaf miner stress compared to control plots. The maximum increase in the foliage damage upon leaf miner infestation was noticed in case of TMV-2 (617.50 %) followed by JL-24 (535.99 %). However, the genotype, K-1812 (123.99 %) has registered the least increase in foliage damage at maturity followed by R-2001-3 (130.26 %) upon leaf miner infestation compared to control condition.

Among the 34 genotypes screened for tolerance to leaf miner infestation, none of them were found to be immune to groundnut leaf miner but two genotypes were found tolerant to the pest, five were moderately tolerant, eighteen were moderately susceptible and remaining nine were highly susceptible (Table 6 and 7). The foliage damage in different genotypes ranged from 19 *per cent* in K-1812 and R-2001-3 to 90 *per cent* in TMV-2. Genotypes K-1812 and R-2001-3 were found to be tolerant for leaf miner with 19 *per cent* foliar damage with a score of 2 on 1 to 10 scale. The genotype Kadiri-9 showed minimum foliage damage of 30 *per cent* followed by HG 2023 suffering 38 *per cent* foliage damage with a damage score of 4, while Dh-256 and KDG-128 and R-8808 recorded 35-40 *per cent* foliage damage with a damage score of 4 and these genotypes were categorized under moderately tolerant types. The genotypes, JSP 39, HG-2021-9 and PBS 12200 recorded 45 *per cent* foliage damage while, ICGV 181029, Dh 232, Dh 299, Dh 257, DBG 22 and Dh2 45 recorded 50 *per cent* foliage damage with a damage score of 5 and the genotypes, GPBD-4, ICGV 15090, Dh 86, TGLPS-3, TAG-24, R-2001-2, HG2021-5, HG2021-7, HG-I-2021-9 recorded 54 to 60 *per cent* foliage damage with a damage score of 6. All these genotypes were categorized under the moderately susceptible types.

In the case of other genotypes viz., TMV-2, HG-2021-16, ICGV 16690, DBG-4, JL-24, G-2-52, GPBD5, ICGV06189 and Dh101, the *per cent* foliage damage registered was between 65 to 90 *percent*, with 7 to 9 damage scale and were classified as highly susceptible genotypes. The genotypes which were screened under natural infestation and pesticide free conditions were categorized into different groups based on *per cent* severity index as per the procedure given by Ghule *et al.* (1988). The

Table 6: Leaf miner scoring of groundnut genotypes at different growth stages

Sl. No.	Genotypes	30 DAS	60 DAS	90DAS	A t maturity
1	TMV-2	2	3	5	9
2	K-1812	1	1	2	2
3	ICGV 181029	2	3	4	5
4	HG 2023	1	2	2	4
5	ICGV15090	1	3	5	6
6	HG-1-2021-9	2	4	4	6
7	HG-2021-16	1	3	6	7
8	HG-2021-5	1	3	4	6
9	HG-2021-7	1	2	5	6
10	HG-2021-9	2	2	3	5
11	Dh-232	1	3	3	5
12	KDG-128	1	2	3	4
13	Dh-256	2	2	3	4
14	R-2001-2	1	3	4	6
15	ICGV 16690	1	3	4	4
16	Kadiri-9	1	2	3	3
17	R-8808	1	2	4	4
18	R-2001-3	1	1	2	2
19	PBS-12200	1	2	3	5
20	G-4	2	3	5	7
21	TAG24	2	3	4	6
22	Dh-257	1	2	3	5
23	JL-24	1	3	4	8
24	Dh-245	2	3	4	5
25	G-2-52	1	2	5	7
26	GPBD-5	2	2	4	7
27	ICGV06189	1	2	5	7
28	TGLPS-3	1	3	4	6
29	Dh-86	1	2	3	6
30	GPBD-4	2	3	4	6
31	Dh-101	2	4	6	8
32	JSP-39	1	2	3	5
33	Dh-299	1	2	3	5
34	DBG-22	2	3	4	5

Note: DAS: Days after sowing

Table 7: Categorization of groundnut genotypes based on foliage damage score due to leaf miner infestation

Sl. No.	Reaction of genotype	Foliage damage (%)	Genotypes
1	Highly tolerant/Immune	0	-NIL-
2	Tolerant	1-20	K-1812 and R-2001-3
3	Moderately tolerant	21-40	HG-2023, KDG-128, Dh-256, Kadiri-9 and R-8808
4	Moderately susceptible	41-60	ICGV181029, ICGV15090, HG-I-2021-9, HG-2021-5, HG-2021-7, HG-2021-9, Dh-232, R-2001-2, PBS-12200, TAG-24, Dh-257, Dh-245, TGLPS-3, Dh-86, GPBD-4, JSP-39, Dh-299 and DBG-22
5	Highly susceptible	61-100	TMV-2, HG-2021-16, ICGV 16690, DBG-4, JL-24, G-2-52, GPBD-5, ICGV 06189 and Dh-101

progressive foliage damage in two tolerant (K-1812 and R-2001-3) and two highly susceptible (TMV-2 and JL-24) genotypes from 30 days to maturity is depicted in Plates 3 to 6.

4.2 Comparative mean performance of Groundnut genotypes for growth and yield traits under control and leaf miner infestation (stress condition)

4.2.1 Per cent difference in the mean performance of genotypes for various traits

The comparison of the mean performance of the genotypes for various traits under leaf miner infestation and control condition (without leaf miner infestation) revealed significant differences for change in *per cent* mean which is depicted in Table 8.

4.2.1.1 Days to 50 per cent flowering (days)

The genotype, HG-2021-9 (5.56 %) has taken 36 days for 50 *per cent* flowering under leaf miner infestation as against 34 days in the control plots which accounts to 5.56 *per cent* increase (delayed by 2 days) in days taken for 50 *per cent* flowering under stress. However, the genotype, G-2-52 has recorded 32.50 days for 50 *per cent* flowering under stress as against 36 days under control which accounts to -10.77 *per cent* (4.50) reduction in the number of days taken for 50 *per cent* of the plant population to bloom under leaf miner infestation stress.

4.2.1.2 Days to maturity (days)

The genotype, JL-24 has taken 115.00 days for days to physiological maturity under leaf miner infestation as against 124.00 days in control plots which accounts for 7.26 *per cent* change followed by TMV-2 with a mean reduction of 7.50 days (6.38) under leaf miner stress. However, the least reduction in the number of days (-4.00 days) taken for maturity under leaf miner infestation stress compared to control was noticed in case of R-2001-3 which accounts for -3.57 *per cent* change (delayed by 4.00 days).

4.2.1.3 Number of mature pods per plant

Least reduction in the number of mature pods per plant under stress condition as against control was noticed in the case of R-2001-3 with mean reduction of 0.33 (3.00 %) followed by K-1812 showing a mean reduction of 0.67 mature pods per plant (5.71 %). Meanwhile, the genotype JL-24 has recorded maximum reduction (60.61 %) followed by R-8808 (56.77 %) in terms of change in percentage mean number of mature pods per plant under leaf miner infestation stress compared to the control condition.

4.2.1.4 Pod yield per plant (g)

All the test genotypes exhibited a reduction in the pod yield per plant under leaf miner infestation stress compared to control plots. The maximum decrease in the pod yield under stress was noticed in case of TMV-2 (48.73 %) followed by Dh101

Table 8: Comparative mean performance of groundnut genotypes for yield and its attributes under leaf miner infestation stress and control condition

Sl. No.	Genotype	Days to 50 <i>per cent</i> flowering			
		Control	Stress	Mean reduction	Change in <i>per cent</i> mean
1	TMV-2	33.50	34.00	-0.50	-1.49
2	K-1812	36.50	38.50	-2.00	-5.48
3	ICGV 181029	40.50	41.00	-0.50	-1.23
4	HG 2023	38.50	39.00	-0.50	-1.30
5	ICGV15090	37.00	39.00	-2.00	-5.41
6	HG-1-2021-9	35.00	37.50	-2.50	-7.14
7	HG-2021-16	38.00	39.00	-1.00	-2.63
8	HG-2021-5	34.50	36.00	-1.50	-4.35
9	HG-2021-7	33.50	36.00	-2.50	-7.46
10	HG-2021-9	36.00	34.00	2.00	5.56
11	Dh-232	37.00	37.50	-0.50	-1.35
12	KDG-128	39.00	39.50	-0.50	-1.28
13	Dh-256	40.00	40.50	-0.50	-1.25
14	R-2001-2	38.50	39.50	-1.00	-2.60
15	ICGV 16690	38.50	39.50	-1.00	-2.60
16	Kadiri-9	34.00	36.00	-2.00	-5.88
17	R-8808	36.00	38.00	-2.00	-5.56
18	R-2001-3	37.50	38.00	-0.50	-1.33
19	PBS-12200	36.50	35.00	1.50	4.11
20	DBG-4	33.50	35.00	-1.50	-4.48
21	TAG24	35.50	37.50	-2.00	-5.63
22	Dh-257	35.00	37.50	-2.50	-7.14
23	JL-24	32.00	33.50	-1.50	-4.62
24	Dh-245	38.50	36.50	2.00	5.19
25	G-2-52	32.50	36.00	-3.50	-10.77
26	GPBD-5	34.50	33.50	1.00	2.82
27	ICGV06189	31.00	34.00	-3.00	-9.68
28	TGLPS-3	32.50	34.50	-2.00	-6.15
29	Dh-86	34.50	36.00	-1.50	-4.35
30	GPBD-4	35.50	37.50	-2.00	-5.63
31	Dh-101	38.00	37.00	1.00	2.63
32	JSP-39	38.50	40.50	-2.00	-5.19
33	Dh-299	37.00	38.00	-1.00	-2.70
34	DBG-22	38.50	40.00	-1.50	-3.90



30 DAS



60 DAS



90 DAS



At maturity

Plate 3: Progressive foliage damage in the genotype K-1812 from 30 days to maturity



30 DAS



60 DAS



90 DAS



At maturity

Plate 4: Progressive foliage damage in the genotype R-2001-3 from 30 days to maturity



30 DAS



60 DAS



90 DAS



At maturity

Plate 5: Progressive foliage damage in the genotype TMV-2 from 30 days to maturity



30 DAS



60 DAS



90 DAS



At maturity

Plate 6: Progressive foliage damage in the genotype JL-24 from 30 days to maturity

Continued....

Sl. No.	Genotype	Days to maturity			
		Control	Stress	Mean reduction	Change in <i>per cent</i> mean
1	TMV-2	117.50	110.00	7.50	6.38
2	K-1812	112.00	111.00	1.00	0.89
3	ICGV 181029	121.00	113.50	7.50	6.20
4	HG 2023	115.00	112.00	3.00	2.61
5	ICGV15090	115.00	114.00	1.00	0.87
6	HG-1-2021-9	114.00	115.00	-1.00	-0.88
7	HG-2021-16	114.00	118.00	-4.00	-3.51
8	HG-2021-5	118.00	113.00	5.00	4.24
9	HG-2021-7	114.00	113.00	1.00	0.88
10	HG-2021-9	115.00	113.00	2.00	1.74
11	Dh-232	115.00	113.50	1.50	1.30
12	KDG-128	125.00	116.50	8.50	6.80
13	Dh-256	114.00	113.00	1.00	0.88
14	R-2001-2	118.00	116.50	1.50	1.27
15	ICGV 16690	114.00	112.00	2.00	1.75
16	Kadiri-9	114.00	113.00	1.00	0.88
17	R-8808	116.00	114.00	2.00	1.72
18	R-2001-3	112.00	116.00	-4.00	-3.57
19	PBS-12200	116.00	113.50	2.50	2.16
20	DBG-4	120.00	118.50	1.50	1.25
21	TAG24	117.00	112.00	5.00	4.27
22	Dh-257	117.00	114.00	3.00	2.56
23	JL-24	124.00	115.00	9.00	7.26
24	Dh-245	118.00	120.00	-2.00	-1.69
25	G-2-52	116.00	114.50	1.50	1.29
26	GPBD-5	116.00	112.00	4.00	3.45
27	ICGV06189	120.00	117.00	3.00	2.50
28	TGLPS-3	118.00	116.00	2.00	1.69
29	Dh-86	114.00	112.50	1.50	1.32
30	GPBD-4	112.00	107.00	5.00	4.46
31	Dh-101	116.00	114.50	1.50	1.29
32	JSP-39	125.00	117.00	8.00	6.40
33	Dh-299	118.00	116.00	2.00	1.69
34	DBG-22	117.00	115.00	2.00	1.71

Continued....

Sl. No.	Genotype	Number of mature pods per plant (g)			
		Control	Stress	Mean reduction	Change in <i>per cent</i> mean
1	TMV-2	8.98	5.33	3.65	40.65
2	K-1812	11.67	11.00	0.67	5.71
3	ICGV 181029	6.00	5.50	0.50	8.33
4	HG 2023	7.77	7.00	0.77	9.91
5	ICGV15090	9.67	8.00	1.67	17.27
6	HG-1-2021-9	9.00	5.00	4.00	44.44
7	HG-2021-16	12.00	5.67	6.33	52.75
8	HG-2021-5	10.33	7.67	2.66	25.75
9	HG-2021-7	9.00	5.33	3.67	40.78
10	HG-2021-9	11.00	7.33	3.67	33.36
11	Dh-232	7.33	6.33	1.00	13.64
12	KDG-128	9.33	7.67	1.67	17.86
13	Dh-256	9.00	8.00	1.00	11.11
14	R-2001-2	11.67	9.67	2.00	17.14
15	ICGV 16690	10.33	7.00	3.33	32.26
16	Kadiri-9	8.33	6.67	1.66	19.93
17	R-8808	12.33	5.33	7.00	56.77
18	R-2001-3	11.00	10.67	0.33	3.00
19	PBS-12200	5.33	4.33	1.00	18.75
20	DBG-4	10.67	6.00	4.67	43.77
21	TAG24	7.33	5.00	2.33	31.82
22	Dh-257	11.67	11.00	0.67	5.71
23	JL-24	11.00	4.33	6.67	60.61
24	Dh-245	10.33	6.95	3.38	32.74
25	G-2-52	11.33	7.00	4.33	38.24
26	GPBD-5	10.33	6.33	4.00	38.71
27	ICGV06189	8.00	6.00	2.00	25.00
28	TGLPS-3	9.33	4.33	5.00	53.57
29	Dh-86	8.33	4.00	4.33	52.00
30	GPBD-4	9.00	5.67	3.33	37.04
31	Dh-101	12.00	8.33	3.67	30.58
32	JSP-39	13.33	8.00	5.33	40.00
33	Dh-299	12.67	7.67	5.00	39.47
34	DBG-22	10.33	7.33	3.00	29.03

Continued....

Sl. No.	Genotype	Pod yield per plant (g)			
		Control	Stress	Mean reduction	Change in <i>per cent</i> mean
1	TMV-2	4.58	2.35	2.23	48.73
2	K-1812	8.67	8.50	0.17	1.92
3	ICGV 181029	8.83	6.75	2.08	23.58
4	HG 2023	6.75	6.17	0.58	8.64
5	ICGV15090	6.75	6.25	0.50	7.41
6	HG-1-2021-9	6.00	5.50	0.50	8.33
7	HG-2021-16	7.58	6.67	0.92	12.09
8	HG-2021-5	8.65	8.33	0.32	3.70
9	HG-2021-7	6.17	5.92	0.25	4.05
10	HG-2021-9	8.67	7.42	1.25	14.42
11	Dh-232	4.42	3.33	1.08	24.53
12	KDG-128	6.58	4.92	1.66	25.28
13	Dh-256	7.16	5.16	2.00	27.93
14	R-2001-2	8.42	7.94	0.48	5.66
15	ICGV 16690	10.08	6.50	3.58	35.54
16	Kadiri-9	6.17	5.50	0.67	10.86
17	R-8808	8.92	6.33	2.58	28.97
18	R-2001-3	7.25	7.00	0.25	3.45
19	PBS-12200	4.58	4.02	0.56	12.29
20	DBG-4	5.15	4.55	0.60	11.65
21	TAG24	6.75	3.50	3.25	48.15
22	Dh-257	11.33	9.42	1.92	16.91
23	JL-24	5.33	3.50	1.83	34.33
24	Dh-245	6.25	3.92	2.33	37.33
25	G-2-52	7.67	5.92	1.75	22.83
26	GPBD-5	6.92	4.33	2.59	37.40
27	ICGV06189	8.95	7.43	1.52	16.98
28	TGLPS-3	6.33	3.75	2.58	40.79
29	Dh-86	4.33	3.75	0.58	13.46
30	GPBD-4	12.08	8.50	3.58	29.66
31	Dh-101	7.83	4.05	3.78	48.30
32	JSP-39	12.08	7.67	4.42	36.55
33	Dh-299	7.83	6.50	1.33	17.02
34	DBG-22	7.50	5.58	1.92	25.56

Continued....

Sl. No.	Genotype	Kernel yield per plant (g)			
		Control	Stress	Mean reduction	Change in <i>per cent</i> mean
1	TMV-2	4.12	2.11	2.01	48.79
2	K-1812	6.81	6.58	0.23	3.31
3	ICGV 181029	5.72	2.06	3.66	63.99
4	HG 2023	5.00	4.75	0.25	5.00
5	ICGV 15090	5.75	5.15	0.60	10.43
6	HG-1-2021-9	4.02	3.80	0.22	5.39
7	HG-2021-16	5.11	2.60	2.51	49.12
8	HG-2021-5	6.35	4.50	1.85	29.13
9	HG-2021-7	4.31	2.53	1.78	41.32
10	HG-2021-9	5.85	2.44	3.41	58.29
11	Dh-232	3.02	2.88	0.14	4.60
12	KDG-128	4.95	3.58	1.37	27.68
13	Dh-256	4.98	3.59	1.39	27.96
14	R-2001-2	6.99	2.73	4.26	60.93
15	ICGV 16690	8.33	3.95	4.38	52.58
16	Kadiri-9	3.92	3.41	0.51	13.06
17	R-8808	5.33	4.55	0.78	14.63
18	R-2001-3	5.98	5.75	0.23	3.85
19	PBS-12200	3.00	2.57	0.43	14.33
20	DBG-4	4.00	2.75	1.25	31.25
21	TAG24	4.95	2.50	2.45	49.49
22	Dh-257	8.33	7.45	0.88	10.56
23	JL-24	4.56	1.50	3.06	67.11
24	Dh-245	5.35	2.95	2.40	44.86
25	G-2-52	4.86	3.00	1.86	38.27
26	GPBD-5	5.33	3.00	2.33	43.71
27	ICGV06189	7.69	6.32	1.37	17.84
28	TGLPS-3	5.55	2.95	2.60	46.85
29	Dh-86	6.79	2.49	4.30	63.34
30	GPBD-4	6.50	2.28	4.22	64.92
31	Dh-101	6.33	2.45	3.88	61.30
32	JSP-39	7.00	4.00	3.00	42.86
33	Dh-299	6.59	2.93	3.66	55.52
34	DBG-22	6.00	3.50	2.50	41.67

Continued....

Sl. No.	Genotype	Pod yield (Kg/ha)			
		Control	Stress	Mean reduction	Change in <i>per cent</i> mean
1	TMV-2	373.25	216.67	156.59	41.95
2	K-1812	2200.00	1950.00	250.00	11.36
3	ICGV 181029	1391.67	339.42	1052.25	75.61
4	HG 2023	1935.00	1083.00	852.00	44.03
5	ICGV 15090	1939.83	823.00	1116.83	57.57
6	HG-1-2021-9	1228.33	668.00	560.33	45.62
7	HG-2021-16	1486.00	1028.00	458.00	30.82
8	HG-2021-5	1395.00	816.50	578.50	41.47
9	HG-2021-7	1266.50	1085.50	181.00	14.29
10	HG-2021-9	1625.00	673.50	951.50	58.55
11	Dh-232	1242.50	816.50	426.00	34.29
12	KDG-128	1320.00	1055.00	265.00	20.08
13	Dh-256	1230.00	1098.50	131.50	10.69
14	R-2001-2	1029.17	530.50	498.67	48.45
15	ICGV 16690	885.00	632.50	252.50	28.53
16	Kadiri-9	1230.00	678.00	552.00	44.88
17	R-8808	425.00	479.67	-54.67	-12.86
18	R-2001-3	1180.00	1050.00	130.00	11.02
19	PBS-12200	1048.00	290.00	758.00	72.33
20	DBG-4	1208.33	726.67	481.67	39.86
21	TAG24	418.33	218.67	199.67	47.73
22	Dh-257	890.83	713.50	177.33	19.91
23	JL-24	280.00	167.00	113.00	40.36
24	Dh-245	600.00	450.50	149.50	24.92
25	G-2-52	588.33	445.25	143.08	24.32
26	GPBD-5	603.33	215.67	387.67	64.25
27	ICGV06189	838.33	507.00	331.33	39.52
28	TGLPS-3	317.50	294.50	23.00	7.24
29	Dh-86	205.00	217.75	-12.75	-6.22
30	GPBD-4	378.33	328.25	50.08	13.24
31	Dh-101	411.67	102.92	308.75	75.00
32	JSP-39	786.50	536.25	250.25	31.82
33	Dh-299	901.50	336.92	564.58	62.63
34	DBG-22	376.67	260.00	116.67	30.97

Continued....

Sl. No.	Genotype	Kernel yield (Kg/ha)			
		Control	Stress	Mean reduction	Change in <i>per cent</i> mean
1	TMV-2	271.50	125.00	146.50	53.96
2	K-1812	1450.00	1300.00	150.00	10.34
3	ICGV 181029	643.00	188.33	454.67	70.71
4	HG 2023	1056.75	716.50	340.25	32.20
5	ICGV 15090	950.17	516.50	433.67	45.64
6	HG-1-2021-9	641.50	600.00	41.50	6.47
7	HG-2021-16	405.00	363.33	41.67	10.29
8	HG-2021-5	766.67	608.33	158.33	20.65
9	HG-2021-7	701.67	691.67	10.00	1.43
10	HG-2021-9	733.33	595.00	138.33	18.86
11	Dh-232	616.67	425.00	191.67	31.08
12	KDG-128	725.00	850.00	-125.00	-17.24
13	Dh-256	983.00	950.00	33.00	3.36
14	R-2001-2	775.00	375.00	400.00	51.61
15	ICGV 16690	345.00	283.33	61.67	17.87
16	Kaidiri-9	666.92	410.00	256.92	38.52
17	R-8808	308.33	153.33	155.00	50.27
18	R-2001-3	866.67	783.33	83.34	9.62
19	PBS-12200	441.67	471.67	-30.00	-6.79
20	DBG-4	550.00	279.50	270.50	49.18
21	TAG24	246.67	176.50	70.17	28.45
22	Dh-257	508.33	443.00	65.33	12.85
23	JL-24	220.00	141.75	78.25	35.57
24	Dh-245	116.50	83.33	33.17	28.47
25	G-2-52	333.33	345.00	-11.67	-3.50
26	GPBD-5	220.00	233.33	-13.33	-6.06
27	ICGV06189	453.33	333.33	120.00	26.47
28	TGLPS-3	190.00	185.00	5.00	2.63
29	Dh-86	100.00	80.00	20.00	20.00
30	GPBD-4	275.00	185.00	90.00	32.73
31	Dh-101	253.34	108.33	145.00	57.24
32	JSP-39	436.67	350.00	86.67	19.85
33	Dh-299	571.67	295.00	276.67	48.40
34	DBG-22	230.00	123.33	106.67	46.38

Continued....

Sl. No.	Genotype	Haulm yield per plant (g)			
		Control	Stress	Mean reduction	Change in <i>per cent</i> mean
1	TMV-2	7.58	5.42	2.17	28.57
2	K-1812	10.83	10.75	0.08	0.77
3	ICGV 181029	17.33	12.96	4.38	25.24
4	HG 2023	10.83	10.56	0.27	2.52
5	ICGV 15090	12.83	11.00	1.83	14.29
6	HG-1-2021-9	11.33	10.33	1.00	8.83
7	HG-2021-16	14.17	13.17	1.00	7.06
8	HG-2021-5	14.91	12.83	2.08	13.95
9	HG-2021-7	5.92	4.51	1.41	23.77
10	HG-2021-9	13.28	12.33	0.95	7.15
11	Dh-232	13.85	11.55	2.30	16.61
12	KDG-128	11.00	10.70	0.30	2.73
13	Dh-256	13.00	12.53	0.47	3.62
14	R-2001-2	9.42	8.55	0.87	9.20
15	ICGV 16690	22.33	14.29	8.04	36.01
16	Kadiri-9	15.33	15.00	0.33	2.15
17	R-8808	12.83	12.05	0.78	6.10
18	R-2001-3	11.22	10.95	0.27	2.41
19	PBS-12200	9.67	9.58	0.08	0.86
20	DBG-4	12.00	11.46	0.54	4.51
21	TAG24	16.17	11.17	5.00	30.93
22	Dh-257	14.50	12.00	2.50	17.24
23	JL-24	9.33	4.00	5.33	57.14
24	Dh-245	15.42	10.17	5.25	34.05
25	G-2-52	17.17	14.33	2.83	16.50
26	GPBD-5	14.42	14.29	0.13	0.87
27	ICGV06189	13.17	13.00	0.17	1.27
28	TGLPS-3	12.00	10.08	1.92	15.97
29	Dh-86	14.67	6.49	8.18	55.74
30	GPBD-4	12.33	8.70	3.63	29.46
31	Dh-101	15.50	9.63	5.88	37.90
32	JSP-39	20.83	13.71	7.13	34.20
33	Dh-299	14.35	11.22	3.13	21.81
34	DBG-22	12.25	11.71	0.54	4.42

(48.30 %). However, the genotype, K-1812 (1.92 %) has registered the least reduction in pod yield followed by R-2001-3 (3.45 %) upon leaf miner infestation stress compared to control condition.

4.2.1.5 Kernel yield per plant (g)

All the test genotypes exhibited reduction in the kernel yield per plant under leaf miner stress compared to control plots. The maximum decrease in kernel yield under stress was noticed in case of JL-24 (67.11 %) followed by GPBD-4 (64.92 %). However, the genotype, K-1812 (3.31 %) has registered the least reduction in kernel yield followed by R-2001-3 (3.85 %) under leaf miner stress compared to control condition.

4.2.1.6 Pod yield (Kg/ha)

The maximum decrease in the pod yield per hectare under leaf miner infestation stress was noticed in case of ICGV 181029 (75.61 %) followed by Dh-101 (75.00 %). However, the genotype, R-8808 (-12.86 %) has registered a least reduction in pod yield per hectare followed by Dh-86 (-6.22 %).

4.2.1.7 Kernel yield (Kg/ha)

The maximum decrease in the kernel yield per hectare under leaf miner infestation stress was noticed in case of ICGV181029 (70.61 %) followed by TMV-2 (53.96 %). However, the genotype, KDG-128 (-17.24 %) has registered a least reduction in pod yield followed by PBS-12200 (-6.79 %).

4.2.1.8 Haulm yield per plant (g)

The genotype, JL-24 has recorded a maximum reduction in the haulm yield per plant (57.14 %) followed by Dh-86 (55.74 %) under leaf miner infestation stress compared to control. However, the genotype K-1812 registered a least reduction in haulm yield per plant (0.77 %) followed by PBS 12200 (0.86 %) upon leaf miner stress compared to control.

4.3 Analysis of variance for yield and yield related traits

Analysis of variance for the twelve characters under investigation has shown significant differences among the genotypes under control as well as leaf miner infestation stress conditions. The mean sum of squares for yield and yield related traits for 34 genotypes under control and leaf miner stress conditions are presented in the Tables 9(a) and 9(b), respectively.

4.4 Estimates of Genetic parameters for yield and yield related traits in groundnut

The genetic variability parameters viz., mean, range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), broad sense heritability (h^2) and genetic advance (GA) as *per cent* of mean for all the twelve characters under control and leaf miner infestation stress are furnished in Tables 10(a) and 10(b), respectively. All the twelve traits under analysis showed a wide range of variation.

Table 9 (a): Analysis of variance for yield and its attributes in control

Source of variation	Degrees of freedom	Mean sum of squares					
		Days to 50 <i>per cent</i> flowering	Days to maturity	Plant height (cm)	Number of primary branches per plant	Number of mature pods per plant	Pod yield per plant (g)
Genotype	33	322.78**	689.36**	467.60**	108.65**	164.94**	172.17**
Replication	1	0.37	1.19	0.26	0.85	0.03	0.68
Error	33	1.25	54.30	77.87	14.62	27.74	35.41
CD (5%)		2.27	2.60	3.12	1.35	1.87	2.10
CD (1%)		3.05	3.51	4.19	1.82	2.51	2.83
CV %		3.07	1.14	6.80	11.21	8.72	12.57

Source of variation	Degrees of freedom	Mean sum of squares					
		Kernel yield per plant (g)	Pod yield (Kg/ha)	Kernel yield (Kg/ha)	Shelling percentage (%)	Test weight (g)	Haulm yield per plant (g)
Genotype	33	149.86**	561388.87**	193729.53**	12264.03**	3143.07**	6104.38**
Replication	1	0.49	34597.72	11096.71	117.03	5.21	11.53
Error	33	29.01	19884.37	19576.16	2155.92	485.73	1408.47
CD (5%)		1.90	286.89	284.66	16.44	7.80	13.29
CD (1%)		2.56	385.42	382.43	22.09	10.48	17.85
CV %		15.09	17.25	18.54	15.61	9.41	14.79

* - Significant @ 5 %, ** - Significant @ 1 % level of probability

Table 9 (b): ANOVA for yield and yield attributes under leaf miner infestation (stress)

Source of variation	Degrees of freedom	Mean sum of squares					
		Days to 50 <i>per cent</i> flowering	Days to maturity	Plant height (cm)	Number of primary branches per plant	Number of mature pods per plant	Pod yield per plant (g)
Genotype	33	502.06**	573.94**	441.79**	165.81**	272.94**	152.36**
Replication	1	0.06	2.88	2.42	0.93	1.47	0.15
Error	33	78.94	62.11	50.37	13.54	36.46	17.21
CD (5%)		3.14	2.79	2.51	1.30	2.14	1.46
CD (1%)		4.22	3.75	3.38	1.75	2.87	1.97
CV %		1.38	1.22	5.89	9.62	11.5	10.66

Source of variation	Degrees of freedom	Mean sum of squares						
		Kernel yield per plant (g)	Pod yield (Kg/ha)	Kernel yield (Kg/ha)	Shelling percentage (%)	Test weight (g)	Haulm yield per plant (g)	Leaf miner damage at maturity
Genotype	33	36.14**	178412.69**	116034.27**	6148.55**	2738.89**	1166.45**	4.93**
Replication	1	0.0045	85941.92	933.88	317.78	0.01	5.43059	0.064
Error	33	7.54	12878.04	5634.71	48184.72	479.63	140.20	0.04
CD (5%)		0.97	230.88	152.72	77.74	7.75	4.19	0.40
CD (1%)		1.30	310.18	205.17	104.44	10.42	5.63	0.54
CV %		18.11	19.02	18.11	11.44	9.66	15.38	3.60

* - Significant @ 5 %, ** - Significant @ 1 % level of probability

Table 10(a): Estimates of Genetic parameters for yield and its attributes in groundnut genotypes under control

Sl No	Traits	Mean	Range		GCV (%)	PCV (%)	h^2_{bs} (%)	GAM (%)
			Minimum	Maximum				
1	Days to 50 per cent flowering	36.32	32.00	41.00	5.82	6.37	83.56	10.96
2	Days to maturity	111.63	107.00	120.00	2.76	2.98	85.39	5.25
3	Plant height (cm)	22.58	16.66	30.66	10.76	12.73	71.45	18.74
4	Number of primary branches per plant	5.91	3.00	9.67	20.09	23.01	76.27	36.15
5	Number of mature pods per plant	10.51	5.33	13.33	13.71	16.25	71.20	23.83
6	Pod yield per plant (g)	6.89	4.33	12.08	17.47	21.53	65.88	29.21
7	Kernel yield per plant (g)	6.21	3.00	7.69	21.78	26.49	67.56	36.87
8	Pod yield (Kg/ha)	940.14	168.33	2200.00	25.35	27.34	73.16	25.92
9	Kernel yield (Kg/ha)	527.19	80.00	1450	22.95	25.97	81.64	33.57
10	Shelling percentage (%)	50.33	23.62	80.00	23.90	28.55	70.10	36.87
11	Test weight (g)	40.76	27.67	60.00	15.56	18.19	73.23	27.44
12	Haulm yield per plant (g)	10.55	5.92	22.33	19.09	24.15	62.51	31.10

GCV = Genotypic coefficient of variation
PCV = Phenotypic coefficient of variation
 h^2_{bs} = Heritability broad sense (%)

GA = Genetic advance
GAM = Genetic advance as per cent mean

Table 10(b): Estimates of Genetic parameters for yield and its attributes in groundnut genotypes under leaf miner infestation

Sl No	Traits	Mean	Range		GCV (%)	PCV (%)	h^2_{bs} (%)	GAM (%)
			Minimum	Maximum				
1	Days to 50 per cent flowering	39.22	33.50	41.00	2.26	2.65	72.83	3.97
2	Days to maturity	112.52	107.00	122.00	2.47	2.76	80.47	4.57
3	Plant height (cm)	20.98	15.33	27.33	11.60	13.01	79.53	23.12
4	Number of primary branches per plant	6.65	4.00	11.70	22.80	24.75	84.90	43.28
5	Number of mature pods per plant	9.14	4.33	11.00	20.70	23.68	76.43	37.28
6	Pod yield per plant (g)	6.77	2.35	9.42	21.23	23.67	79.71	38.87
7	Kernel yield per plant (g)	2.64	1.50	7.45	24.93	30.81	65.46	41.55
8	Pod yield (Kg/ha)	566.77	102.92	1098.50	21.76	24.57	58.33	37.27
9	Kernel yield (Kg/ha)	392.85	83.33	950.00	20.81	24.22	80.74	40.55
10	Shelling percentage (%)	24.00	51.77	80.00	27.17	34.61	61.62	43.94
11	Test weight (g)	39.47	26.67	54.17	14.82	17.69	70.20	25.58
12	Haulm yield per plant (g)	9.67	4.51	15.00	29.42	33.19	78.54	53.70
13	Leaf miner damage at maturity	5.45	2.00	9.00	29.73	27.95	88.38	54.12

GCV = Genotypic coefficient of variation
PCV = Phenotypic coefficient of variation
 h^2_{bs} = Heritability broad sense (%)

GA = Genetic advance
GAM = Genetic advance as per cent mean

4.4.1 Days to 50 per cent flowering (days)

A high heritability value of 83.56 *per cent* coupled with a moderate genetic advance as *per cent* of mean (10.96) and overall trait mean value of 36.32 with a range of 32.00 to 41.00 days were recorded for days to 50 *per cent* flowering. Lower values of genotypic and phenotypic coefficients of variation (5.82 and 6.37 *per cent*, respectively.) were recorded for this trait under control condition.

Meanwhile in leaf miner infestation stress condition, heritability was found to be high with value of 72.83 *per cent* with a lower value of genetic advance as *per cent* of mean (3.97). Character mean estimated was 39.22 with a range of 33.50 to 41.00 days. This trait showed low genotypic and phenotypic coefficient of variation of 2.26 and 2.65 *per cent*, respectively.

4.4.2 Days to maturity (days)

In control, low genotypic (2.76 %) and phenotypic (2.98 %) coefficients of variation were found coupled with a high estimate of heritability (85.39 %) and low genetic advance as *per cent* of mean (5.25) was observed for days to maturity. The character shows a mean number of days to maturity value of 111.63 days, with a range of 107 to 120 days.

However, in leaf miner infested stress condition, days to maturity was in the range of 107 to 122 days with an overall mean of 113 days. This trait exhibited a low genotypic and phenotypic coefficient of variation of 2.47 and 2.76 *per cent*, respectively. A high heritability of 80.47 *per cent* but low genetic advance over mean of 4.57 *per cent* was recorded for this trait.

4.4.3 Plant height (cm)

The plant height at maturity under control condition was in the range of 16.66 to 30.66 cm with a mean of 22.58 cm. A moderate, genotypic and phenotypic coefficient of variation of 10.76 and 12.73 *per cent*, respectively, were recorded for this trait. A high heritability of 71.45 *per cent* coupled with a moderate genetic advance over mean of 18.74 *per cent* was recorded for this trait.

On the other hand, under leaf miner infested stress condition, for plant height, the mean value observed was 20.98 cm, with a range of 15.33 to 27.33 cm. A high broad sense heritability of 79.53 *per cent* and high genetic advance as *per cent* mean of 23.12 was observed for this trait. The genotypic and phenotypic coefficient of variation was moderate with values of 11.60 and 13.01 *per cent*, respectively for plant height.

4.4.4 Number of primary branches per plant

Number of primary branches per plant ranged from 3.00 to 9.67 with a mean value of 5.91. The estimates of GCV and PCV were high with values 20.09 and 23.01

per cent, respectively. High heritability (76.27 %) coupled with high genetic advance as *per cent* of mean (36.15 %) was observed for this character under control condition.

However, in leaf miner infestation stress condition, the mean number of primary branches per plant was 6.65 with a range of 4.00 to 11.17. Further, the estimates of GCV (22.80 %), and PCV (24.75 %) were found to be high with high heritability (84.90 %) and high genetic advance over mean (43.28 %) for this trait.

4.4.5 Number of mature pods per plant

Substantial variation was observed for number of mature pods per plant and it was varied from 4.33 to 11.00 with a mean value of 9.14 mature pods per plant. The estimates of GCV and PCV were found to be high with the values of 20.70 and 23.68 *per cent*, respectively. High heritability (76.43 %) combined with high genetic advance as *per cent* of mean (37.28 %) were observed for this character under leaf miner infested stress condition.

Whereas, in control the mean number of mature pods per plant was 10.91 with a range of 5.33 to 13.33. The estimates of GCV (13.71) and PCV (16.25) were found to be high with high heritability (71.20) and high genetic advance over mean (23.83) for this trait.

4.4.6 Pod yield per plant (g)

Considerable variation was observed for pod yield per plant with a minimum yield of 4.33 g and a maximum of 12.08 g. The overall mean value for pod yield per plant was 6.89 g. This trait recorded moderate GCV (17.47 %) and PCV (21.53 %). High heritability (65.88 %) coupled with high genetic advance as *per cent* of mean (29.21 %) was observed for this character.

However, under leaf miner stress condition, the mean pod yield per plant was 6.77 g with a range of 2.35 g to 9.42 g. The estimates of GCV and PCV recorded a moderate value of 21.23 and 23.67 *per cent*, respectively. The heritability for this trait was high (79.71 %), coupled with a high genetic advance over mean (38.87 %).

4.4.7 Kernel yield per plant (g)

Considerable variation was observed for this character with a minimum of 3.00 g and a maximum of 7.69 g. The overall mean value for kernel yield per plant was 6.21 g. Estimates of GCV and PCV were found to be high with the values 21.78 and 26.49 *per cent*, respectively. High heritability (67.56 %) coupled with high genetic advance as *per cent* of mean (36.87 %) was observed for this character.

On the contrary, under leaf miner stress condition, the kernel yield per plant shows a mean of 2.64 g with a range of 1.50 to 7.45 g. The PCV and GCV were high

with values of 24.93 and 30.81 *per cent*, respectively. This trait exhibited a high heritability of 65.46 *per cent* with high (41.55 %) genetic advance over mean.

4.4.8 Pod yield (Kg/ha)

Considerable variation was observed for this character with a minimum of 168.33 Kg and a maximum of 2200 Kg. The overall mean value for kernel yield per plant was 940.14 Kg. Estimates of GCV and PCV were found to be high with values 25.35 and 27.34 *per cent*, respectively. High heritability (73.16 %) coupled with high genetic advance as *per cent* of mean (25.92 %) was observed for this character under control.

However, under leaf miner stress condition, the mean pod yield per ha was 566.77 Kg with a range of 102.92 Kg to 1098.50 Kg. The estimates of GCV and PCV recorded a high value of 21.76 and 24.57 *per cent*, respectively. The heritability for this trait was medium (58.33 %), coupled with a high genetic advance over mean (37.27 %).

4.4.9 Kernel yield (Kg/ha)

Considerable variation was observed for kernel yield per ha with a minimum yield of 80.00 Kg and a maximum of 1450.00 Kg. The overall mean value for pod yield per plant was 527.19 Kg. This trait recorded higher GCV (22.95 %) and PCV (25.97 %). High heritability (81.64 %) coupled with high genetic advance as *per cent* of mean (33.57 %) was observed for this character under control situation.

On the contrary, under leaf miner stress condition, the kernel yield per ha shows a mean of 392.85 Kg with range of 83.33 to 950.00 Kg. The GCV and PCV were high with values of 20.81 and 24.22 *per cent*, respectively. This trait exhibited a high heritability of 80.74 *per cent* with high genetic advance over mean (40.55 %).

4.4.10 Shelling percentage (%)

For this trait, high heritability estimates of 70.10 *per cent* and a high genetic advance as *per cent* of mean (36.87) was recorded under control condition. Further, high genotypic and phenotypic coefficients of variation were recorded (23.90 and 28.55 *per cent*, respectively). The average value for the shelling percentage was 50.33, with a range of 23.62 to 80.00 under control.

In case of leaf miner stress condition, the shelling percentage was ranging from 24.00 to 80.00 with a mean of 51.77. The genotypic and phenotypic coefficients of variation were high with their values being 27.17 and 34.61 *per cent*, respectively. The heritability for the trait was high (61.62 %) with high genetic advance over mean (43.94 %).

4.4.11 Test weight (g)

Test weight or 100 kernel weight exhibited considerable variation and ranged from 27.67 g to 60.00 g with a mean of 40.76 g. The estimates of GCV and PCV were 15.56 and 18.19 *per cent*, respectively. Further, this trait exhibited high heritability (73.23 %) combined with high genetic advance as *per cent* of mean (27.44 %).

When the same observations were recorded under stress condition, the GCV and PCV estimates were moderate with values of 14.82 and 17.69 *per cent*, respectively. High heritability (70.20 %) coupled with high genetic advance over mean of 25.58 *per cent* was found for this trait. The test weight ranged from 26.67 to 54.17 with an average value of 39.47.

4.4.12 Haulm yield per plant (g)

The mean of haulm yield per plant, under control condition was 10.55 g, ranging from 5.92 to 22.33 g. A high heritability of 62.51 *per cent* was observed with a high genetic advance as *per cent* mean (31.10 %). The moderate phenotypic and genotypic coefficients of variation were observed for this trait (19.09 and 24.15 %, respectively).

On the contrary, this trait under leaf miner stress situation, exhibited a mean of 9.67 g with a range of 4.51 to 15.00 g. The PCV and GCV were moderate with a value of 16.85 and 16.60 *per cent*, respectively. The heritability for the trait was high (78.54 %), with high (33.68 %) genetic advance over mean.

4.4.13 Leaf miner damage at maturity

High phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) of 29.73 and 27.95, respectively for foliage damage score due to leaf miner infestation at maturity was observed. High heritability coupled with high genetic advance as *per cent* of mean (GAM) were observed for foliage damage ($h^2=88.38$; GAM=54.12). The leaf miner score ranged from 2.00 to 9.00 with a mean of 5.45. In contrast to this, there is less or no leaf miner damage observed with a score of 1.00 with 1.00 to 10.00 *per cent* foliage damage in case of control condition wherein plants were pesticide sprayed to control leaf miner infestation

4.5 Correlation coefficient analysis for yield and yield attributing characters in groundnut genotypes

The phenotypic association of twelve characters of the groundnut were recorded to establish the type of association present among them. The correlation analysis allows the breeders to understand the characteristics of the mutual component on which selection may be premised for genetic improvement. It shows the strength of the character's relationship with yield and other characters mentioned. The result for the

correlation between seed yield and other associated traits at the phenotypic level under control and leaf miner infestation stress condition is presented in the Tables 11(a) and 11(b), respectively.

4.5.1 Correlation of pod yield per plant with other traits

Under control condition phenotypically pod yield per plant recorded significant positive association with plant height (0.28), number of primary branches per plant (0.29), number of mature pods per plant (0.48), haulm yield (0.55), shelling percentage (0.52), kernel yield per plant (0.68), kernel yield per ha (0.70), test weight (0.34) and pod yield per ha (0.81). But pod yield per plant recorded a non-significant association with days to 50 *per cent* flowering (-0.12) and days to maturity (-0.14).

Meanwhile in leaf miner infestation stress condition, pod yield per plant recorded significant positive association with number of primary branches per plant (0.35), plant height (0.29), number of mature pods per plant (0.55) and haulm yield (0.31), shelling percentage (0.25), kernel yield per ha (0.77), kernel yield per plant (0.64), test weight (0.40), and pod yield per ha (0.79). Traits like days to maturity (-0.26) and leaf miner damage (-0.37) had shown a negative and significant association with pod yield. The non-significant association was found for days to 50 *per cent* flowering (-0.21) with pod yield per plant.

4.5.2 Correlation among yield components

4.5.2.1 Days to 50 *per cent* flowering

Under leaf miner stress condition, days to maturity (0.78) had positive significant association at the phenotypic level with days to 50 *per cent* flowering. With this trait, number of primary branches per plant (0.14), number of mature pods per plant (0.08), haulm yield per plant (0.14) and leaf miner damage (0.12) had shown non-significant association. However, plant height (-0.70), shelling percentage (-0.39) and test weight (-0.56) had shown significant negative association. Kernel yield per ha (-0.15), kernel yield per plant (-0.20), pod yield per ha (-0.11) and pod yield per plant (-0.21) had shown negative and non-significant association.

On the other hand, under control condition, the traits *viz.*, days to maturity (0.55) and number of primary branches per plant (0.27) at the phenotypic level showed a significant positive association with days to 50 *per cent* flowering. With this trait, number of mature pods per plant (0.10), haulm yield per plant (0.05) and shelling percentage (0.02) showed non-significant association. However, plant height (-0.05), kernel yield per ha (-0.01), test weight (-0.05), pod yield per ha (-0.07) and pod yield per plant (-0.12) had shown non-significant association.

Table 11(a): Phenotypic correlation for pod yield and its attributes in genotypes of groundnut under control

X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉	X ₁₀	X ₁₁	X ₁₂	
1.00	0.55**	-0.048	0.27 *	0.10	0.015	-0.08	-0.01	0.02	-0.05	0.05	-0.12	X ₁
	1.00	0.22	0.29 *	0.11	-0.10	-0.12	-0.07	-0.05	-0.02	-0.05	-0.14	X ₂
		1.00	0.15	0.24 **	0.38**	0.35**	0.20	0.07	0.28 *	0.12	0.28 *	X ₃
			1.00	0.34 **	0.29**	0.27 *	0.24 *	0.26*	0.42**	0.12	0.29 *	X ₄
				1.00	0.51**	0.49**	0.36**	0.27*	0.42 **	0.08	0.48**	X ₅
					1.00	0.80*	0.51 **	0.48 **	0.52**	0.31**	0.68**	X ₆
						1.00	0.27*	0.18	0.48**	0.40**	0.81*	X ₇
							1.00	0.78**	0.24	0.38 **	0.70**	X ₈
								1.00	0.15	0.26*	0.52**	X ₉
									1.00	0.033	0.34 **	X ₁₀
										1.00	0.55**	X ₁₁
											1.00	X ₁₂

* - Significant @ 5%, ** - Significant @ 1% level of probability

X₁ = Days to 50 per cent flowering

X₂ = Days to maturity

X₃ = Plant height (cm)

X₄ = Number of primary branches per plant

X₅ = Number of mature pods per plant

X₆ = Kernel yield per plant (g)

X₇ = Pod yield (Kg/ha)

X₈ = Kernel yield (Kg/ha)

X₉ = Shelling percentage (%)

X₁₀ = Test weight (g)

X₁₁ = Haulm yield per plant (g)

X₁₂ = Pod yield per plant (g)

Table 11(b): Phenotypic correlation for pod yield and its attributes in genotypes of groundnut under leaf miner infestation (stress)

X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉	X ₁₀	X ₁₁	X ₁₂	X ₁₃	
1.00	0.78**	-0.70**	0.14	0.08	-0.20	-0.11	-0.15	-0.39**	-0.56**	0.14	0.12	-0.21	X ₁
	1.00	-0.86**	-0.02	-0.06	-0.29*	-0.21	-0.27*	-0.46**	-0.66**	0.15	0.22	-0.26*	X ₂
		1.00	0.10	0.11	0.29*	0.28*	0.30*	0.37**	0.58**	-0.10	-0.16	0.29*	X ₃
			1.00	0.36**	0.38**	0.22	0.24**	-0.05	0.0028	0.31**	-0.31**	0.35**	X ₄
				1.00	0.49**	0.53**	0.49**	0.14	0.18	0.45**	-0.24*	0.55**	X ₅
					1.00	0.45**	0.49**	0.39**	0.39**	0.43**	-0.51**	0.64**	X ₆
						1.00	0.82**	0.22	0.31*	0.20	-0.24*	0.79*	X ₇
							1.00	0.44**	0.44**	0.17	-0.29*	0.77**	X ₈
								1.00	0.67**	0.025	-0.41**	0.25*	X ₉
									1.00	0.023	-0.33*	0.40**	X ₁₀
										1.00	-0.15	0.31**	X ₁₁
											1.00	-0.37**	X ₁₂
												1.00	X ₁₃

* - Significant @ 5%, ** - Significant @ 1% level of probability

X₁ = Days to 50 per cent flowering

X₂ = Days to maturity

X₃ = Plant height (cm)

X₄ = Number of primary branches per plant

X₅ = Number of mature pods per plant

X₆ = Kernel yield per plant (g)

X₇ = Pod yield (Kg/ha)

X₈ = Kernel yield (Kg/ha)

X₉ = Shelling percentage (%)

X₁₀ = Test weight (g)

X₁₁ = Haulm yield per plant (g)

X₁₂ = Leaf miner damage at maturity

X₁₃ = Pod yield per plant (g)

4.5.2.2 Days to maturity (days)

The traits *viz.*, days to 50 *per cent* flowering (0.55) and number of primary branches per plant (0.29) at phenotypic level showed a significant positive association with days to maturity. With this trait, plant height (0.22) and number of mature pods per plant (0.11) showed a non-significant association. However, haulm yield (-0.05), shelling percentage (-0.05), kernel yield per ha (-0.07), kernel yield per plant (-0.10), test weight (-0.02), pod yield per ha (-0.12) and pod yield per plant (-0.14) had non-significant association with days to 50 *per cent* flowering under control condition.

Under leaf miner stress condition, days to 50 *per cent* flowering (0.78) had shown positive significant association with days to maturity. The trait haulm yield (0.15) and leaf miner (0.22) showed a non-significant association with this trait. Other traits like, plant height (-0.86), shelling percentage (-0.46), kernel yield per ha (-0.27), kernel yield per plant (-0.29) and test weight (-0.66) showed a significant negative association with days to maturity. However, the number of primary branches per plant (-0.02), number of mature pods per plant (-0.06) and pod yield per ha (-0.21) showed non-significant association.

4.5.2.3 Plant height (cm)

A significant positive association under control condition was exhibited by plant height with traits like number of mature pods per plant (0.24), kernel yield per plant (0.38), test weight (0.28), pod yield per ha (0.35) and pod yield per plant (0.28). Whereas, days to maturity (0.22), number of primary branches per plant (0.15), haulm yield (0.12), shelling percentage (0.07), kernel yield per ha (0.20) and days to 50 *per cent* flowering (-0.05) had shown a non-significant association with plant height.

Under leaf miner stress condition, plant height had a significant positive association with shelling percentage (0.37), kernel yield per ha (0.30), kernel yield per plant (0.29), test weight (0.58), pod yield per ha (0.28) and pod yield per plant (0.29). The trait, number of mature pods per plant (0.11) and number of primary branches per plant (0.10) exhibited non-significant correlation. Non-significant association was found with haulm yield per plant (-0.10) and leaf miner damage (-0.16) but days to maturity (-0.86) and days to 50 *per cent* flowering (-0.70) had shown significant negative association with plant height.

4.5.2.4 Number of primary branches per plant

Number of primary branches per plant under controlled condition exhibited a significant positive association with days to 50 *per cent* flowering (0.27), number of mature pods per plant (0.34), days to maturity (0.29), shelling percentage (0.26), kernel yield per ha (0.24), kernel yield per plant (0.29), test weight (0.42), pod yield per ha (0.27) and pod yield per plant (0.29). Whereas, the traits, plant height (0.15) and haulm yield (0.12) showed non-significant association.

Meanwhile, under leaf miner stress condition, a significant positive association was shown by number of mature pods per plant (0.36), haulm yield (0.31), kernel yield per ha (0.24), kernel yield per plant (0.38), and pod yield per plant (0.35). The characters showed non-significant association viz., days to 50 *per cent* flowering (0.14), plant height (0.10), test weight (0.01) and pod yield per ha (0.22). Leaf miner damage (-0.31) showed significant negative association with this trait but days to maturity (-0.02) and shelling percentage (-0.05) had shown non-significant association.

4.5.2.5 Number of mature pods per plant

Under control condition, characters like plant height (0.24), number of primary branches per plant (0.34), shelling percentage (0.27), kernel yield per ha (0.36), kernel yield per plant (0.51), test weight (0.42), pod yield per ha (0.49) and pod yield per plant (0.48) had exhibited positive significant association. Non-significant association was seen for traits like days to 50 *per cent* flowering (0.10), days to maturity (0.11) and haulm yield (0.08).

Under leaf miner affected condition, number of primary branches per plant (0.36), haulm yield (0.45), kernel yield per ha (0.49), kernel yield per plant (0.49), pod yield per ha (0.53) and pod yield per plant (0.55) had shown positive significant association. Traits, days to 50 *per cent* flowering (0.08), plant height (0.11), test weight (0.18) and shelling percentage (0.14) showed non-significant association. However, days to maturity (-0.06) exhibited non-significant association but leaf miner damage (-0.24) has shown significant negative association.

4.5.2.6 Kernel yield per plant (g)

Under control field condition, characters like, plant height (0.38), number of primary branches per plant (0.29), number of mature pods per plant (0.51), haulm yield (0.31), shelling percentage (0.48), kernel yield per ha (0.51), test weight (0.52), pod yield per ha (0.80) and pod yield per plant (0.68) had shown positive and significant association with kernel yield per plant. Non-significant association was recorded with days to 50 *per cent* flowering (0.01). Whereas, days to maturity (-0.10) solely contributed to non-significant association with this trait.

On the contrary, under leaf miner affected condition, plant height (0.29), number of primary branches per plant (0.38), number of mature pods per plant (0.49), haulm yield (0.43), shelling percentage (0.39), kernel yield per ha (0.49), test weight (0.39), pod yield per ha (0.45) and pod yield per plant (0.64) had estimated for positive significant correlation. Significant negative association was shown by days to maturity (-0.29) and leaf miner damage (-0.51). A non-significance association was recorded for days to 50 *per cent* flowering (-0.20) with kernel yield per plant.

4.5.2.7 Pod yield (Kg/ha)

Under control condition, plant height (0.35), number of primary branches per plant (0.27), number of mature pods per plant (0.49), haulm yield (0.40), kernel yield per ha (0.27), kernel yield per plant (0.80), test weight (0.48) and pod yield per plant (0.81) had positive and significant association. The trait shelling percentage (0.18) exhibited positive non-significant association. Negative non-significance was found by days to 50 *per cent* flowering (-0.08) and days to maturity (-0.12).

On the contrary, under leaf miner stress condition, plant height (0.28), number of mature pods per plant (0.53), kernel yield per ha (0.82), test weight (0.31), pod yield per ha (0.82) and pod yield per plant (0.79) have shown positive significant association. Non-significant association was shown by number of primary branches per plant (0.22), haulm yield (0.20) and shelling percentage (0.22). Non-significant association was recorded with days to 50 *per cent* flowering (-0.11) and days to maturity (-0.21) but leaf miner damage (-0.24) showed negative significant association.

4.5.2.8 Kernel yield (Kg/ha)

Under control condition, number of primary branches per plant (0.24), number of mature pods per plant (0.36), haulm yield (0.38), shelling percentage (0.78), kernel yield per plant (0.51), pod yield per ha (0.27) and pod yield per plant (0.78) have recorded positive and significant association with this trait. The traits like, plant height (0.20) and test weight (0.24) had shown non-significant association. Non-significant association was observed with days to 50 *per cent* flowering (-0.01) and days to maturity (-0.07).

On the other hand, under leaf miner affected condition, plant height (0.30), number of primary branches per plant (0.24), number of mature pods per plant (0.49), shelling percentage (0.44), kernel yield per plant (0.49), test weight (0.44), pod yield per ha (0.82) and pod yield per plant (0.77) had recorded positive significant association with kernel yield per ha. Whereas, days to 50 *per cent* flowering (-0.15) had non-significant correlation with this trait. But, days to maturity (-0.27) and leaf miner damage (-0.29) have recorded significant negative association with kernel yield (Kg/ha). The trait, haulm yield (0.17) had exhibited non-significant association with this trait.

4.5.2.9 Shelling percentage (%)

Under control field condition, characters like, number of primary branches per plant (0.26), number of mature pods per plant (0.27), haulm yield (0.26), kernel yield per ha (0.78), kernel yield per plant (0.48) and pod yield per plant (0.52) had shown positive significant association with shelling percentage. Traits, days to 50 *per cent* flowering (0.02), plant height (0.07), test weight (0.15) and pod yield per ha (0.18) had

shown non-significant association. Days to maturity (-0.05) has shown non-significant association with shelling percentage.

Under leaf miner affected condition, plant height (0.37), kernel yield per ha (0.44), kernel yield per plant (0.39), pod yield per plant (0.25), test weight (0.67) and pod yield per plant (0.25) had shown a positive significant association. Traits like, number of mature pods per plant (0.14) and haulm yield (0.02) have shown non-significance association with shelling percentage. Number of pods per plant (0.17) exhibited non-significant association with shelling percentage. Characters, days to 50 *per cent* flowering (-0.39), days to maturity (-0.46) and leaf miner damage (-0.41) have exhibited negative significant association, whereas number of primary branches per plant (-0.05) showed non-significant association with this trait.

4.5.2.10 Test weight (g)

Under leaf miner affected condition, plant height (0.58), shelling percentage (0.67), kernel yield per ha (0.44), kernel yield per plant (0.39), pod yield per ha (0.31) and pod yield per plant (0.40) had positive and significant association. The traits like number of primary branches per plant (0.01), number of mature pods per plant (0.18) and haulm yield (0.02) had shown non-significant association. Negative significant association was found by days to 50 *per cent* flowering (-0.56), days to maturity (-0.66) and leaf miner damage (-0.33).

On the other hand, under control condition, plant height (0.28), number of primary branches per plant (0.42), number of mature pods per plant (0.42), kernel yield per plant (0.52), pod yield per ha (0.48), and pod yield per plant (0.34) had recorded positive significant association with test weight. Whereas, haulm yield (0.03), shelling percentage (0.15) and kernel yield per ha (0.24) was estimated for positive non-significance with this trait. Traits, days to 50 *per cent* flowering (-0.05) and days to maturity (-0.02) had exhibited non-significant association.

4.5.2.11 Haulm yield (g)

Under normal condition, this trait exhibited positive significant association with shelling percentage (0.26), kernel yield per ha (0.38), kernel yield per plant (0.31), pod yield per ha (0.40) and pod yield per plant (0.55). Non-significant association was observed with characters like days to 50 *per cent* flowering (0.05), plant height (0.12), number of primary branches per plant (0.12), number of mature pods per plant (0.08) and test weight (0.03). With this trait, days to maturity (-0.05) exhibited non-significant association.

On the contrary, under leaf miner affected condition, positive significant association was noticed for traits, *viz.*, number of branches per plant (0.31), number of

mature pods per plant (0.45), kernel yield per plant (0.43) and pod yield per plant (0.31). A non-significant association was noticed with days to 50 *per cent* flowering (0.14), days to maturity (0.15), shelling percentage (0.02), test weight (0.02), kernel yield per ha (0.17) and pod yield per ha (0.20). The character, plant height (-0.10) and leaf miner damage (-0.15) has recorded non-significant association.

4.5.12 Leaf miner damage at maturity

Under leaf miner infestation, the leaf miner foliage damage showed negative significant association with number of primary branches per plant (-0.31), number of mature pods per plant (-0.24), shelling percentage (-0.41), kernel yield per ha (-0.29), kernel yield per plant (-0.51), test weight (-0.33), pod yield per ha (-0.24) and pod yield per plant (-0.37). Traits like plant height (-0.16) and haulm yield (-0.15) exhibited non-significant association. With this trait, non-significant association was observed by days to 50 *per cent* flowering (0.12) and days to maturity (0.22).

DISCUSSION

V DISCUSSION

Groundnut is an important oil and protein source for a large portion of the population in Asia, Africa and America. Its seeds are rich source of edible oil (43-55 %) and protein (25 to 28 %). The success of any crop improvement programme largely depends on the genetic variability present in the population. Hence, ascertaining the variability for tolerance to leaf miner, yield and its components provides an insight into the extent of variability for the concerned trait and subsequent selection for the desired genotype.

The discussion on the following aspects of the present study is presented in this chapter

- 5.1 Comparative mean performance of groundnut genotypes for tolerance to leaf miner at different growth stages
- 5.2 Comparative mean performance of groundnut genotypes for growth and yield traits under control and leaf miner infestation
- 5.3 Analysis of Variance and genetic parameters for yield and yield attributes under control and leaf miner infestation
- 5.4 Phenotypic correlation analysis under control and leaf miner infestation

5.1 Comparative mean performance of groundnut genotypes for tolerance to leaf miner at different growth stages

Under leaf miner infestation stress and control conditions, the mean *per cent* foliage damage was estimated at four different crop growth stages. At all the stages, significant differences for change in *per cent* mean were noticed. Higher leaf miner infestation damage was observed in the genotypes JL-24, TMV-2, GPBD-4 and Dh-101 (Figure 1 and 2).

Among the test genotypes screened, none of them were found to be immune to groundnut leaf miner but two were found tolerant to the pest, five were moderately tolerant, eighteen were moderately susceptible and remaining nine were highly susceptible (Table 10). The foliage damage in different genotypes ranged from 19 in K-1812 to 90 *per cent* in TMV-2. Genotypes K-1812 and R-2001-3 were found to be tolerant to leaf miner with minimal foliage damage (19 to 20 %) at maturity stage in the plots where no pest control measures were taken up indicating that, these two genotypes having an inherent mechanism to tolerate leaf miner damage as compared to remaining test genotypes. The genotype Kadiri-9 showed minimum foliage damage of 30 *per cent* followed by HG 2023 suffering 38 *per cent* damage with a damage score of 4, while KDG-128, R-8808, and Dh-256 recorded 35- 40 *per cent* foliage damage with a damage score of 4 and these genotypes were categorized under moderately tolerant types. The genotypes, JSP 39, HG-2021-9 and PBS-12200 recorded 45 *per cent*

foliage damage while, ICGV 181029, Dh-232, Dh-299, Dh-257, DBG 22 and Dh 245 recorded up to 50 *per cent* foliage damage with damage score of 5 and GPBD 4, ICGV15090, Dh 86, TGLPS 3, TAG 24, R 2001-2, HG-2021-5, HG-2021-7, HG-I-2021-9 recorded 54 to 60 *per cent* damage with a damage score of 6 (Figure 3). All these genotypes were categorized under the moderately susceptible types.

In the case of other genotypes *viz.*, TMV-2, HG-2021-16, ICGV 16690, DBG4, JL24, G2-52, GPBD5, ICGV06189 and Dh 101, the *per cent* foliage damage registered was between 65 to 90 *per cent*, with 7 to 9 damage scale and were classified as highly susceptible genotypes.

The results of present investigation are in line with the findings of Praveena *et al.* (2011). TMV-2 recorded the highest number of larvae per plant with higher damage which was categorized as highly susceptible which is in similarity with the results of Bindra (1970), Mahadevan *et al.* (1988), Rao (2002) and Manjunath (2002). Performance of TAG-24 (moderately susceptible) is in line with the findings of Jena *et al.* (1996) and Praveen (2005). The performance of JL-24 is similar with the findings of Waykule *et al.* (2020). R-8808 was found to be moderately tolerant, the genotypes Dh-101, GPBD-5, G-2-52 and TMV-2 were found to be susceptible to leaf miner which is in accordance with the results of Praveena *et al.* (2011).

5.2 Comparative mean performance of groundnut genotypes for growth and yield traits under control and leaf miner infestation

Under leaf miner infestation stress and control conditions, 34 genotypes exhibited a marked difference in the mean values of many traits. Majority of the traits exhibited a reduction in their mean values including yield upon leaf miner infestation

5.2.1 Per se mean performance of genotypes for different traits

The *per se* mean performance of groundnut genotypes exhibited a marked difference under control and leaf miner infestation conditions for different traits under study. Same traits were studied for same set of genotypes under both the conditions. Among the characters assessed, most of the traits exhibited decrease in *per cent* mean under leaf miner infestation when compared with that of control for days to maturity, number of mature pods per plant, pod yield per plant, kernel yield per plant, pod yield per hectare, kernel yield per hectare and haulm yield per plant. However, an increase in *per cent* mean under leaf miner infestation was seen for character like days to 50 *per cent* flowering when compared with that of control.

The *per cent* difference in days to fifty *per cent* flowering among 34 genotypes was found to be highest for HG-2021-9 (5.56 %) and the difference was found to be minimum for G-2-52 (-10.77 %). The increased days for 50 *per cent* flowering was

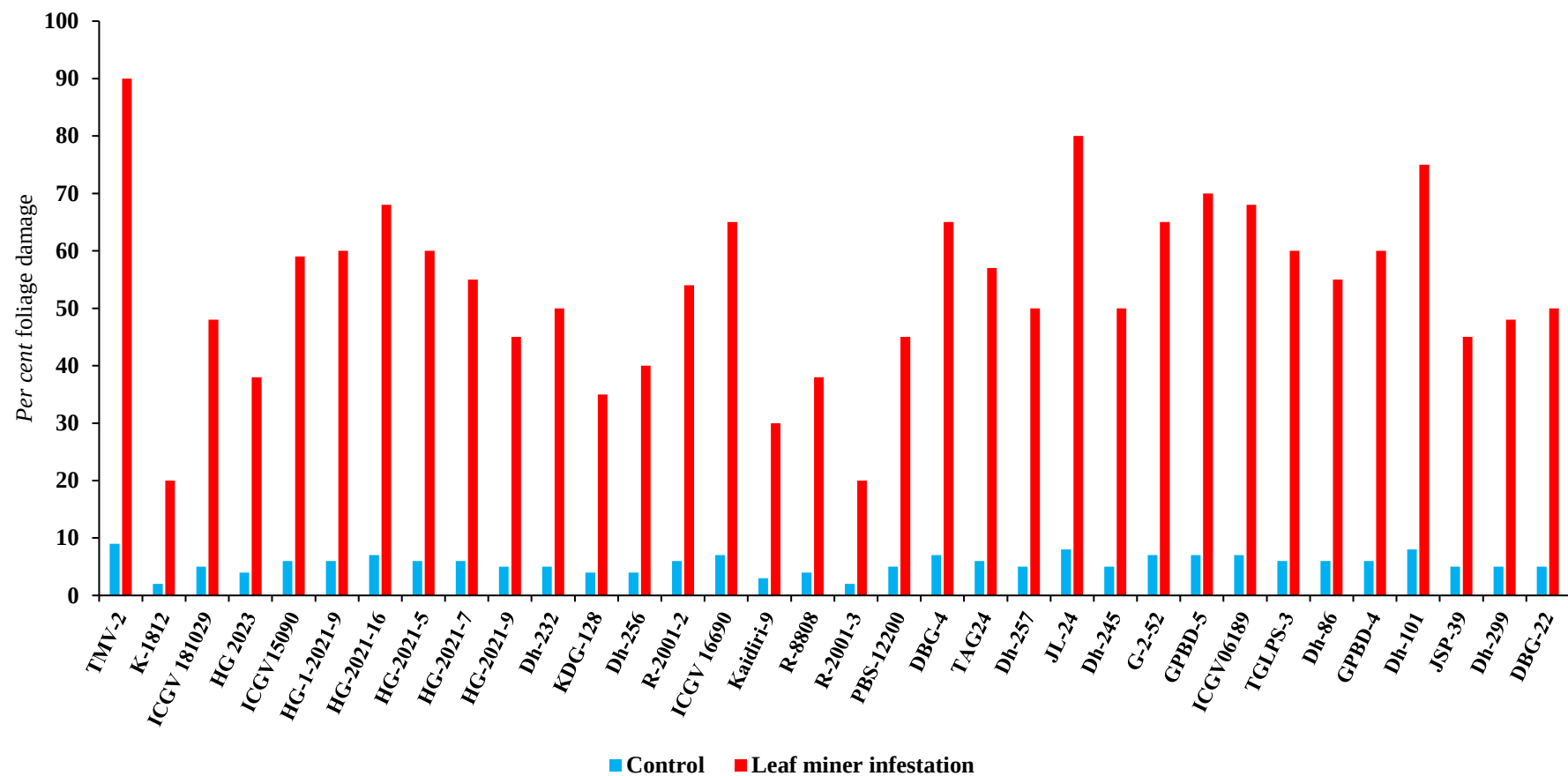


Fig. 1: *Per cent foliage damage under control and leaf miner infestation stress condition at maturity*

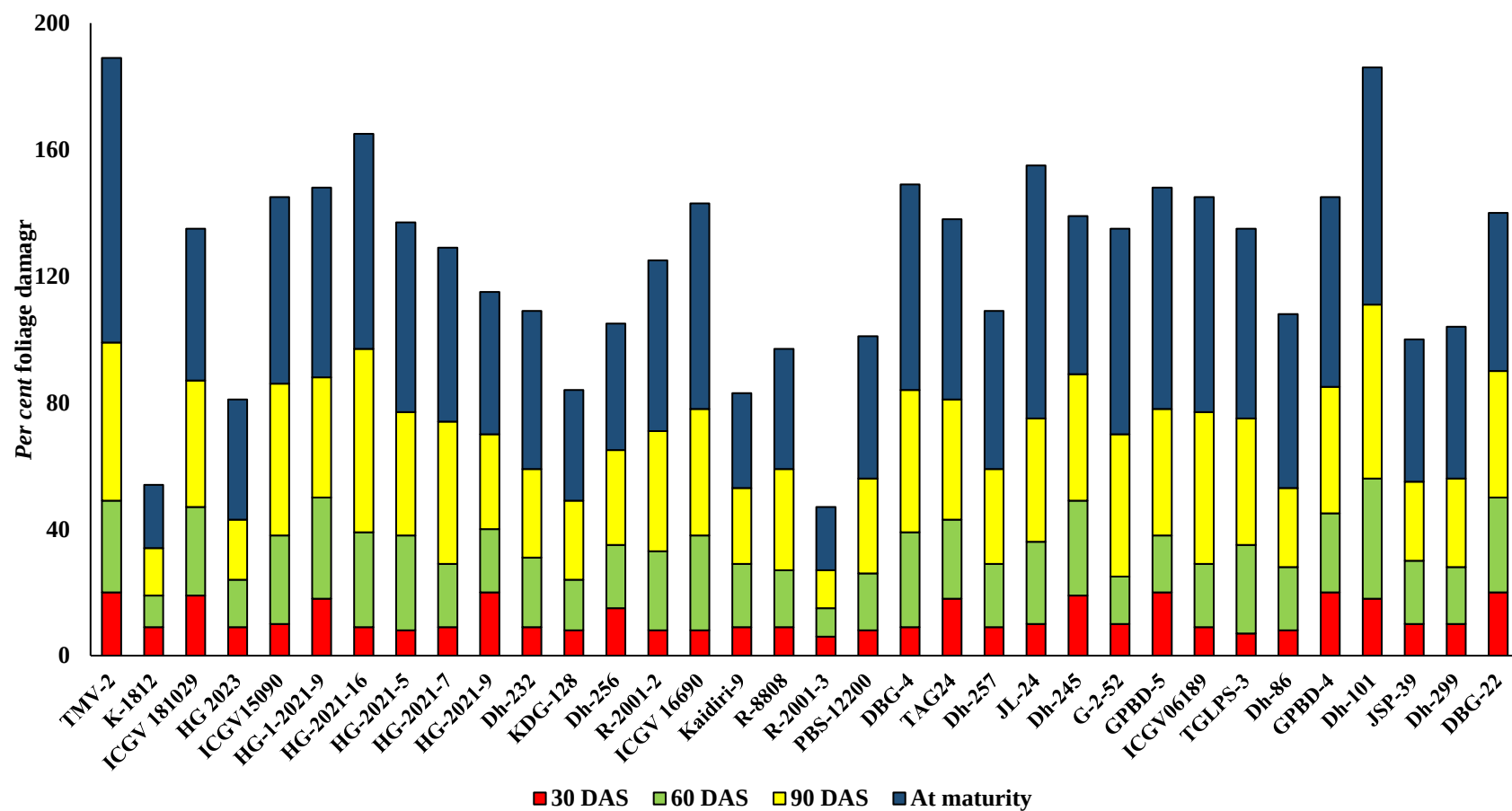


Figure 2: Depiction of progressive foliage damage at 30, 60, 90 DAS and maturity stage in different genotypes

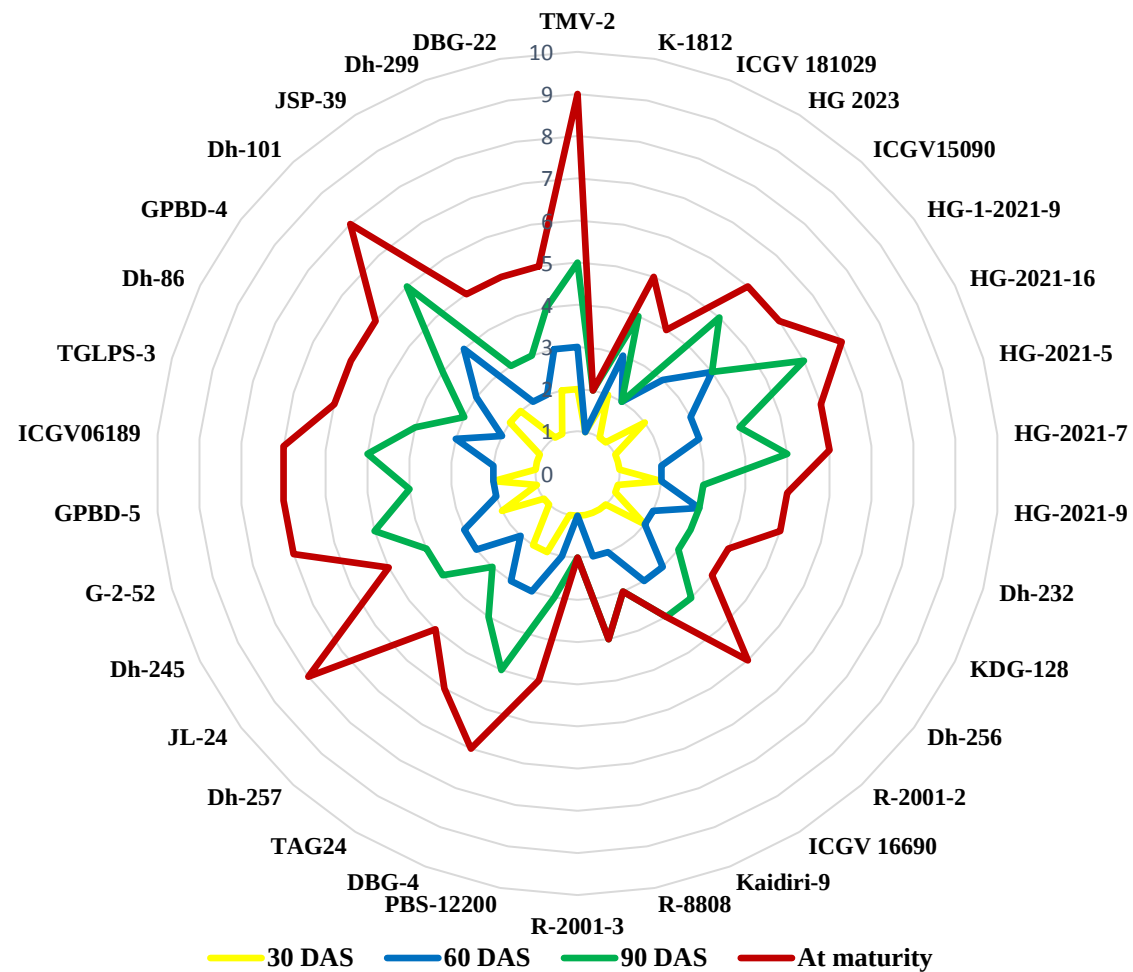


Fig 3: Leaf miner scoring of genotypes at different growth stages

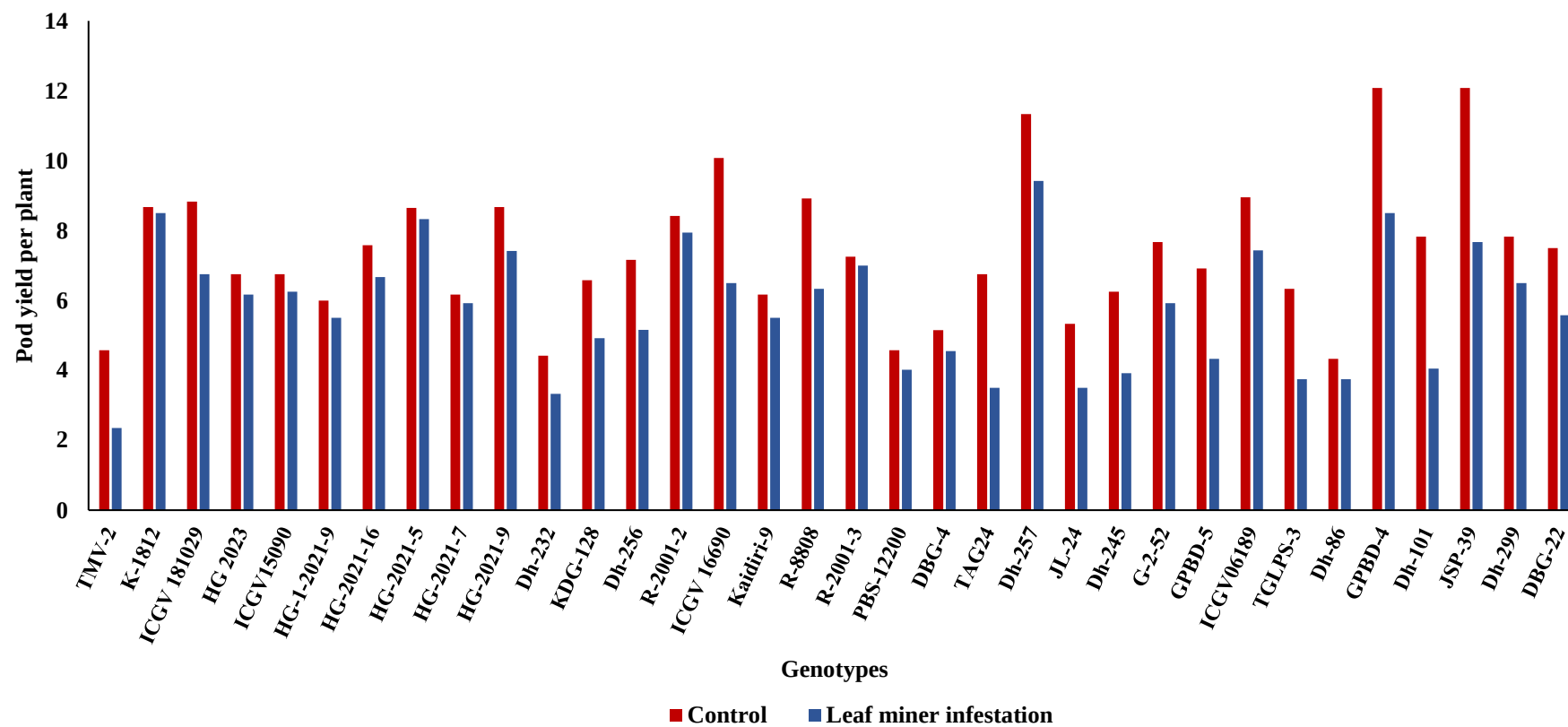


Figure 4: Comparison of pod yield under control and leaf miner infestation stress in different genotypes

recorded in some genotypes could be due to heterogenous soil conditions and leaf miner infestation or any other unknown reasons.

Maximum *per cent* difference for days to maturity between leaf miner infestation stress and control was found in JL-24 which has taken 115 days under leaf miner infestation as against 124.00 days under control followed by TMV-2. However, the minimum difference was exhibited by R-2001-3 with 116 days to maturity under leaf miner infestation as against 112.00 days under control indicating its ability to withstand leaf miner infestation. The maximum reduction in days to maturity as exhibited by JL-24 is one of the important resilience mechanism evolved by plants to counter abiotic and biotic stresses.

Number of mature pods per plant exhibited highest *per cent* difference in case of JL-24 followed by Kaidiri-9 while minimum *per cent* difference was shown by R-2001-3 followed by K-1812. This might be due to compromised physiological or metabolic activity under biotic stress causing poor plant development or could be due to increased flower and pod abortions.

In the case of pod yield per plant, the *per cent* difference was found to be lowest in K-1812 followed by R-2001-3 as depicted in Figure 4. Highest *per cent* difference for pod yield per plant was found in TMV-2 followed by Dh 101. The reduction in yield by susceptible genotype, TMV-2 could be due to compromised performance of yield attributing trait like number mature pods per plant and reduced photosynthetic area due to leaf miner damage of the foliage.

Kernel yield per plant was found to exhibit a large *per cent* difference under control and leaf miner infestation stress condition. Maximum *per cent* difference was noticed in JL-24 followed by GPBD-4 which may be due to reduced pod yield and number of pods per plant. Whereas, lowest *per cent* difference was observed in K-1812 followed by R-2001-3 which is due to ability of these two genotypes to withstand leaf miner damage.

The maximum decrease in the pod yield per hectare under leaf miner infestation stress was noticed in case of ICGV 181029 followed by Dh-101 which is due to decreased number of mature pods per plant and pod yield per plant. However, the genotype, R-8808 has registered a least reduction in pod yield per hectare followed by Dh-86 which is due to their ability to withstand the leaf miner damage.

The maximum decrease in the kernel yield per hectare under leaf miner infestation was noticed in case of ICGV181029 followed by TMV-2. However, the genotype, KDG-128 has registered a least reduction in pod yield followed by PBS-12200. The leaf miner damage impairs plant performance through limiting

photosynthate production thereby causing reduction in growth and interruption of the supply of assimilates to pod and seed development.

The genotype, JL-24 has recorded a maximum reduction in the haulm yield per plant followed by Dh 86 under leaf miner infestation stress compared to control. Haulm yield was reduced due to the increased foliage damage by leaf miner. However, the genotype K-1812 registered a least reduction in haulm yield per plant followed by K-9 upon leaf miner stress compared to control which indicating their better inherent mechanism for leaf miner tolerance.

5.3 Analysis of Variance and Genetic parameters for yield and yield related traits

Analysis of variance was done to check for significant differences among the genotypes. Various sources revealed that, the mean sum of squares among the 34 genotypes screened showed significant differences, representing the presence of sufficient variability among the 34 genotypes of groundnut for all the traits which can be used for further crop improvement programs. These results are in line with the findings of Korat *et al.* (2009) and Deepthi *et al.* (2022).

For a crop improvement program, it is a prerequisite to maintain the genetic variability that allows identification of promising genes in the genotypes that can be incorporated in the breeding programs to develop promising cultivars.

The total variance present in the material will not accurately be represented by the range and mean values. Therefore, to understand the level of variability existing for the character, actual variance needs to be estimated. The phenotypic variance indicates the amount of variance which is due to the differences in phenotypic value whereas the genotypic variance indicates the magnitude of variance arising due to differences in genotypic values.

The absolute values of phenotypic and genotypic variance cannot be used for comparing the degree of variability for different characters because the units in which the characters are measured are different. To make comparisons, the co-efficient of variation which quantifies variance as percentage of mean can be utilized. Higher estimates of these characters indicate greater variability and vice-versa. In the same context small difference between the phenotypic co-efficient of variation (PCV) and genotypic co-efficient of variation (GCV) suggests that lesser influence of the environment in the expression of characters. The range of variation was quite high for all the traits in genotypes along with checks suggesting that these characters may be enhanced by individual plant selection.

In the 34 genotypes studied under control condition, estimated values of GCV and PCV were relatively high for traits like number of primary branches per plant,

number of mature pods per plant, haulm yield, kernel yield per plant, kernel yield per ha, test weight, shelling percentage, pod yield per hectare and pod yield per plant suggesting that there is presence of considerable variability. Hence, individual plant selection can be practiced for the above-mentioned characters to get higher yields. Similar results of high GCV and PCV for these traits were obtained by Kukanur *et al.* (2014), Yadlapalli (2014), Sowmya and Nadaf (2022) and Kulheri *et al.* (2022). Higher GCV and PCV for pod yield (Kg/ha) and kernel yield (Kg/ha) also obtained by Shukla and Rai (2014).

Plant height, number of mature pods per plant and test weight had moderate GCV and PCV. This indicates the presence of variability for these characters. These results are on par with the findings of Thirumala Rao *et al.* (2014). Vishnuvardhan *et al.* (2012), Kulheri *et al.* (2022), Sukrutha *et al.* (2023) and Sowmya and Nadaf (2022) reported similar findings for plant height. Further, Gowda *et al.* (1996), Venkataramana *et al.* (2001) and Kavani *et al.* (2004) also obtained matching results for test weight in case of groundnut.

Days to 50 *per cent* flowering and days to physiological maturity showed low GCV and PCV which indicates less variability for these traits. Korat *et al.* (2009), Zaman *et al.* (2011), Sathish (2014), Shinde *et al.* (2010) and Yadav *et al.* (2023) observed a similar trend but John *et al.* (2012) found high GCV and PCV for days to 50 *per cent* flowering.

A similar trend has been noticed under stress condition for all the traits except number of mature pods per plant, suggesting a possibility of additive gene action and hence there exists a scope for a simple selection scheme for the improvement of these characteristics. Number of mature pods per plant exhibited high GCV and PCV. Similar results were obtained by Deshmukh *et al.* (1993), Manoharan *et al.* (1990), Shobha *et al.* (2012) and Deepthi *et al.* (2022).

To have an exact idea of the heritable portion of variability, it is necessary to estimate heritability for each character. The relative strength of the characters and the effectiveness of the selection processes are represented by broad sense heritability estimates. Broad sense heritability gives an idea about observed variability which is attributable to genetic difference. The difference between PCV and GCV estimates indicates the extent of heritability. If the difference is low, it indicates high heritability. While wide differences indicate considerable influence of the environment leading to low heritability estimates.

Even though the coefficient of variation gives an idea about the amount of variability, it does not give an exact idea about the extent of inheritance of the character. Heritability estimates by separating the environmental influence from the total

variability, indicate the accuracy with which a genotype can be assessed by its phenotypic performance, thus, permitting greater effectiveness of phenotypic selection. However, its use would be limited as it is influenced to a great extent by the environment and genotypes included.

Heritability value alone cannot provide information on the amount of genetic progress that would result from the selection of best individuals. Johnson *et al.*, (1955) reported that heritability estimates along with genetic gain would be more useful than alone in predicting the effectiveness of selecting the best individuals. Therefore, it is necessary to consider the predicted genetic advance along with high heritability estimates as a tool in the selection program for better efficiency in the selection.

A relative comparison of heritability values and expected genetic gain expressed as *per cent* of the mean gives an idea about the nature of gene action governing a particular character. High heritability coupled with high genetic advance indicates the presence of lesser environmental influence and prevalence of additive gene action in the expression of the trait. However, lower values of genetic advance reveal the prevalence of a narrow range of variability, high gene interaction or non-additive gene action. Moderate values of genetic advance suggest that both additive and non-additive gene actions may be responsible for the expression of traits.

In the present investigation, higher heritability along with high genetic advance as *per cent* of mean was noticed for the characters like number of primary branches per plant, number of mature pods per plant, haulm yield per plant, shelling percentage, kernel yield per plant, pod yield per plant, test weight and leaf miner. Parallel findings were obtained by Venkataramana *et al.* (2001) for test weight and kernel yield per plant, Zaman *et al.* (2011) for kernel yield per plant, kernel yield per hectare, 100 kernel weight, number of mature nuts per plant and number of branches per plant, Kukanur *et al.* (2014) for primary branches per plant, pods per plant, kernel yield per plant, test weight and pod yield per plant. Recently, Sowmya and Nadaf (2022) also reported similar trend of heritability and genetic advance as *per cent* of mean for the number of primary branches per plant, number of pods per plant, kernel yield, shelling percentage and test weight. Likewise, Deepthi *et al.* (2022) reported high heritability coupled with GAM for traits, haulm yield per plant, shelling percentage, number of mature pods and pod yield per plant. Shukla and Rai (2014) reported high heritability with high GAM for kernel yield per hectare and pod yield per hectare.

This demonstrates that there is ample opportunity for these traits to be improved in future breeding programs and develop or isolate high-yielding groundnut genotypes through single plant selection. There is also ample scope for the selection of genotype to breed for tolerance to leaf miner coupled with higher yield in groundnut.

High heritability coupled with moderate genetic advance as *per cent* of mean was observed for days to fifty *per cent* flowering and plant height which was also observed by Vasanthi *et al.* (1998) and in contrast to this under stress condition plant height shows high heritability coupled with high genetic advance as *per cent* mean which was similar with the findings of Makhan *et al.* (2003) and Golakia *et al.* (2005).

Low genetic advance as *per cent* mean for days to maturity indicates the prevalence of a narrow range of variability. Similar results were reported by Reddy and Guptha (1992) and Praveen (2006) in groundnut. For traits with low values of genetic advance and heritability, selection becomes inefficient because low or nearly low genetic advance suggests the presence of non-additive gene action.

5.4 Phenotypic correlation analysis under control and leaf miner infestation

The yield of a plant is a dependent character. It relies on numerous defining characteristics that would influence its outcome. The effects of yield-attributing traits must be taken into account for a selection program to be successful. The relationship between the yield and its component characters has been displayed through the correlation studies in the present investigation.

The correlation coefficient assists the breeder in determining the relative importance of yield components for indirect selection for yield and in the current study, phenotypic correlation between pod yield per plant with its component characters and among the component traits themselves were studied in genotypes of groundnut.

Under control condition, phenotypically pod yield per plant recorded a significant positive association with plant height, number of primary branches per plant, number of mature pods per plant, haulm yield, shelling percentage, kernel yield per plant, kernel yield per ha, test weight and pod yield per ha signifying the importance of the above traits in the successful enhancement of yield. The result on above mentioned traits implies that, these are the vital criteria that are to be used in the guidelines for the selection of elite lines from the base population as a substitute for direct selection for yield. Similar findings were obtained by John *et al.* (2005), Venkataramana *et al.* (2001), Zaman *et al.* (2011), Narasimhulu *et al.* (2012), Mohapatra and Khan (2020) for number of mature pods, haulm yield per plant, kernel yield per plant, shelling percentage and test weight, and Kukanur *et al.* (2014) for number of pods per plant, plant height, number of branches per plant, kernel yield per plant. Habite (2023) observed significant positive correlation between kernel yield per hectare and pod yield per hectare.

Pod yield per plant also recorded a non-significant association with days to 50 *per cent* flowering and days to maturity. The same results were reported by Reddy and Gupta (1992), Vasanthi *et al.* (1998), Venkataramana *et al.* (2001), Belay *et al.* (2018),

Mane *et al.* (2008) for days to 50 *per cent* flowering, and Korat *et al.* (2010) for days to physiological maturity.

Meanwhile under leaf miner infestation, pod yield per plant recorded significant positive association with number of primary branches per plant, plant height, number of mature pods per plant, haulm yield, shelling percentage, kernel yield per hectare, kernel yield per plant, test weight, and pod yield per hectare. Traits like days to maturity had shown a negative and significant association with pod yield. Non-significant association was found for days to 50 *per cent* flowering. Similar findings were obtained by Mahalakshmi *et al.* (2005), Zaman *et al.* (2011), Sathish (2014), and Gupta *et al.* (2015) for days to 50 *per cent* flowering, days to physiological maturity, shelling percentage, test weight and Deshmukh *et al.* (1993) for days to 50 *per cent* flowering, Reddy and Gupta (1992) for kernel yield per plant, number of mature pods per plant and shelling percentage.

Under both situations (Leaf miner free and leaf miner infestation), characters like, plant height, number of primary branches per plant, number of mature pods per plant, haulm yield, shelling percentage, kernel yield per hectare, test weight, pod yield per hectare and pod yield per plant had shown positive and significant association with kernel yield per plant. Parallel results were obtained by Shobha *et al.* (2012), Kumar *et al.* (2014), Gupta *et al.* (2015), Aparna *et al.* (2018) and Pachauri and Sikarwar (2022). Non-significant association was recorded for days to 50 *per cent* flowering and negative non-significance for days to physiological maturity which is in accordance with the findings of Reddy *et al.* (2017) and Mubai *et al.* (2020). However, under leaf miner infestation condition, kernel yield exhibited significant negative association with days to physiological maturity. Non-significant association was recorded for days to 50 *per cent* flowering.

Under control condition, days to 50 *per cent* flowering was significantly and positively associated with days to physiological maturity and number of primary branches per plant. Similar findings were established by Korat *et al.* (2010) and Yadav *et al.* (2023) for days to maturity. In case of days to physiological maturity, there was positive and significant association with number of primary branches per plant. Traits, days to maturity and days to 50 *per cent* flowering showed negative association with pod yield and kernel yield. Equivalent results were obtained by Mallikarjuna (2001), Mane *et al.* (2008) and Gupta *et al.* (2015).

In case of stress condition, the trait, days to 50 *per cent* flowering was significantly and positively associated with days to physiological maturity and plant height. Days to maturity showed a significant negative association with plant height, shelling percentage, kernel yield per hectare, kernel yield per plant and test weight.

Parallel findings were reported by Hampannavar *et al.* (2018) and Babariya and Dobariya (2012).

Plant height is positively correlated with the number of mature pods per plant and test weight, pod yield and kernel yield per plant under both conditions. This suggests that improvement for these traits can be done in a single selection program. Similar results were reported by Deshmukh *et al.* (1993), Reddi *et al.* (1991), Venkataraman *et al.* (2001), and John *et al.* (2007) in groundnut.

Under both conditions, the number of primary branches per plant showed a significant positive association with number of mature pods per plant, haulm yield, kernel yield per hectare, kernel yield per plant, and pod yield per plant. Equivalent results are obtained by Vasanthi *et al.* (2015) and Kumar *et al.* (2019) for kernel yield and number of pods per plant.

Number of primary branches per plant, haulm yield, kernel yield per hectare, kernel yield per plant, pod yield per hectare and pod yield per plant had shown positive significant association under both the field conditions (leaf miner infested and leaf miner free). Similar findings were obtained by Nirmala and Jayalakshmi (2015) and Godhani *et al.* (2020).

The number mature pods per plant expressed a significant positive correlation with number of primary branches per plant, haulm yield, kernel yield per hectare, kernel yield per plant, pod yield per hectare and pod yield per plant showed a positive significant association. In the case of control, significant positive correlation for plant height, test weight and shelling percentage. These findings are in accordance with Sathish (2014) and Barad *et al.* (2021).

Under both the conditions, haulm yield had positive significant association with kernel yield per hectare, kernel yield per plant, pod yield per hectare and pod yield per plant. Hampannavar *et al.* (2018) has reported that, haulm yield per plant had significant positive correlation with dry pod yield per plant.

Under control (leaf miner free), condition characters like, number of primary branches per plant, number of mature pods per plant, haulm yield, kernel yield per hectare, kernel yield per plant and pod yield per plant had shown positive significant association with shelling percentage. Whereas, under leaf miner stress condition, shelling percentage showed positive significant relation with plant height, kernel yield per hectare, kernel yield per plant, test weight and pod yield per plant. Equivalent results were obtained by Tirkey *et al.* (2018) for test weight, pod yield and kernel yield per plant.

In control condition, plant height, number of primary branches per plant, number of mature pods per plant, kernel yield per plant, pod yield per hectare, and pod yield per plant had recorded for positive significance with test weight. Under leaf miner stress condition, plant height, shelling percentage, kernel yield per hectare, kernel yield per plant, pod yield per hectare and pod yield per plant had estimated for positive and significant association. These results are in line with the findings of Narasimhulu *et al.* (2012), Tirumala Rao *et al.* (2014), Belay *et al.* (2018) and Attia *et al.* (2022) for number of mature pods per plant and shelling percentage.

Conclusion

The groundnut genotypes in the present investigation were found to possess potential variation for many economic traits and degree of tolerance to leaf miner infestation. Selection would be effective for crop improvement for tolerance to leaf miner and other economic traits. Further, there is a scope for isolation of promising lines for yield improvement. Traits showing significant association with yield, as well as having high heritability and high genetic advance are chosen for hybridization to combine different desirable traits to achieve yield maximization in groundnut.

It may be concluded that, for yield improvement programme, number of branches per plant, number of mature pods per plant and kernel yield per plant can be pyramided in breeding program for total yield improvement in a control and leaf miner stress condition. The genotypes, K-1812 and R-2001-3 were identified as leaf miner tolerant genotypes present study.

Future line of work

Depending on the information obtained and results available from the current investigation, the following future line of work could be proposed.

1. Leaf miner tolerant genotypes (K-1812 and R-2001-3) identified in current investigation have recorded significantly higher yield under stress. However, the genotypes can be further evaluated in different environments and under varying levels of manual imposition of leaf miner infestation to compare their potentiality and to confirm their stable performance.
2. In the present research carried out, the traits *viz.*, days to 50 *per cent* flowering, plant height, number of primary branches per plant, number of mature pods per plant, haulm yield per plant, test weight, shelling percentage, kernel yield per plant, kernel yield per hectare, pod yield per hectare and pod yield per plant exhibited high heritability coupled with high genetic advance over *per cent* mean. Selection of these traits will be more useful in identifying genotypes for higher yield.
3. Identified leaf miner tolerant genotypes can be utilized as source of parents in breeding programmes to develop varieties which are need of the day under prevailing climate change-scenario.
4. Molecular and biochemical characterization of these genotypes for leaf miner tolerance can be done.

SUMMARY

VI SUMMARY

Groundnut (*Arachis hypogaea* L.) is one of the economically important oilseed crops of India. Leaf miner (*Aproaerema modicella* D.) is one of the important insect causing up to 50 *per cent* yield loss. The groundnut leaf miner, *Aproaerema modicella* Deventer, belongs to the family Gelechiidae and the order Lepidoptera is an oligophagous insect pest and feeds only on leguminous host plants and is a serious pest of groundnut in both rainy and post rainy seasons in India.

Developing genotypes that withstand leaf miner infestation and ensure higher yield is one of the important goals of plant breeders. Several efforts have been made to enhance the productivity of groundnut crop under biotic stress situations by improving the attributes damaged by stress. Thus, there is a need to identify leaf miner tolerant cultivars to minimize the reduction in production and productivity of groundnut.

In this context, the present study entitled "Genetic variability studies in Groundnut for tolerance to leaf miner (*Aproaerema modicella* D.)" was carried out to elucidate the information on leaf miner tolerance of genotypes and the nature of the association of yield component characters on pod yield and to assess the genetic variability, heritability and genetic advance over mean for yield and its components. The present experiment was conducted in a randomized complete block design with two replications each in control (with suitable pest control measures) and stress (without any pest control measures) at ZAHRS, Hiriya during the early *Rabi* season of 2022-23. The experimental material consisted of 34 groundnut genotypes including checks.

The observations were recorded on thirteen traits *viz.*, days to 50 *per cent* flowering, days to maturity, plant height, number of primary branches per plant, number of mature pods per plant, pod yield per plant, kernel yield per plant, pod yield per hectare, kernel yield per hectare, shelling percentage, test weight, haulm yield per plant and foliage damage (leaf miner scoring) at four different stages.

Analysis of variance for leaf miner damage score based on *per cent* foliage damage revealed high GCV and PCV, high heritability coupled with genetic advance as *per cent* mean at different intervals *i.e.*, 30 days after sowing, 60 days after sowing, 90 days after sowing and maturity. This indicates that selection for leaf miner (*Aproaerema modicella* D.) tolerance is effective. Change in *per cent* mean for *per cent* foliage damage at different intervals/growth stages under control and stress (leaf miner infestation) is done to study the effect of leaf miner under infestation.

Under leaf miner stress condition, identifying genotypes that withstand leaf miner infestation stress was analyzed through leaf miner scores (based on *per cent*

foliage damage). We identified tolerant genotypes for leaf miner based on damage score and change in *per cent* of mean for yield and contributing traits under control and stress condition. Out of the 34 genotypes studied, none exhibited immunity to the pest; however, two genotypes demonstrated noteworthy tolerance, five were moderately tolerant, eighteen displayed moderate susceptibility, and the remaining nine were highly susceptible. This classification system offers insights into the genotypes varying degrees of resilience to leaf miner stress, guiding future strategies for plant breeding and agricultural management.

The results of field screening of groundnut genotypes against leaf miner revealed that, the genotypes K-1812 and R-2001-3 were tolerant with a least foliage damage of 20 *percent* (score 2) whereas K-9, HG 2023, R-8808, KDG-128 and Dh-256 were found to be moderately tolerant with 30 to 40 *per cent* foliar damage (3-4 score), and remaining genotypes were susceptible with more than 50 *per cent* foliar damage similar to that of susceptible check, TMV-2. Identified leaf miner tolerant genotypes have recorded significantly higher yield under stress. The tolerant genotypes identified in the present study can be cultivated in endemic areas of leaf miner and also utilized in breeding programmes for leaf miner tolerance.

The perusal of ANOVA revealed the existence of highly significant differences among the genotypes for all the traits studied. A wide range of phenotypic and genotypic variation and high heritability coupled with high genetic advance over mean was recorded for most of the traits. It indicates the broad genetic base and a lesser amount of environmental influence which specifies the prevalence of genetic factors controlling variability for these traits. Hence, early and straight forward-generation selection programs would be effective for improvement and there is a plentiful scope for isolation of promising lines for leaf miner tolerance and yield.

Higher heritability and high genetic advance over mean were recorded for many quantitative traits under leaf miner infestation stress. The high genetic advance over mean under stress conditions was because of higher phenotypic variance, even though heritability remained the same under non-stress conditions. These findings revealed the importance of such characters giving more response under stress for crop improvement in groundnut.

Number of primary branches per plant, haulm yield per plant, kernel yield per plant, kernel yield per hectare, test weight, shelling percentage and pod yield per plant recorded high PCV and GCV values under leaf miner stress indicating the presence of a high amount of variability and better scope for improving these trait. Further, the characters like plant height, number of mature pods per plant and test weight recorded moderate PCV and GCV, suggesting the existence of relatively moderate variability for these traits, which could be utilized to improve these traits through simple selection

programs. Days to 50 *per cent* flowering and days to physiological maturity showed low GCV and PCV, indicating less variability for these traits. Selection of these for improvement of yield is not practical.

In this study, the characters *viz.*, primary branches per plant, number of mature pods per plant, haulm yield per plant, shelling percentage, kernel yield per plant, pod yield per plant, test weight and foliage damage due to leaf miner exhibited higher heritability with high genetic advance over mean, indicating the presence of considerable variation and also showed the presence of additive gene effects. Further, it also suggested that the environmental effects have least influence the expression of these characters. Hence, these characters can be considered during groundnut yield improvement.

High heritability coupled with moderate genetic advance as *per cent* of mean was observed for days to fifty *per cent* flowering and plant height. Low genetic advance as *per cent* mean for days to maturity indicates the prevalence of a narrow range of variability. Selection becomes inefficient for traits with low genetic advance and heritability values because low or nearly low genetic advance suggests the presence of non-additive gene activity.

The association study exhibited that, pod yield recorded a significant and positive association with plant height, number of primary branches per plant, number of mature pods per plant, haulm yield, shelling percentage, kernel yield per plant, kernel yield per hectare, test weight and pod yield per hectare. This depicts that whenever there is an increase in the contribution of these traits, the increase in pod yield can be achieved directly. They were mutually and directly linked to pod yield in groundnut. Hence, these characters can also be regarded as requirements for the selection of higher yield.

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