GENETIC STUDIES IN F_2 POPULATIONS OF SIX GROUNDNUT (*Arachis hypogaea* L.) CROSSES

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B.Sc. (Ag)

MASTER OF SCIENCE IN AGRICULTURE
(GENETICS AND PLANT BREEDING)

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BY
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THESIS SUBMITTED TO THE
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2011

DECLARATION

I, **Ms. ANJU MARIAM JOSEPH** hereby declare that the thesis entitled "**GENETIC STUDIES IN F_2 POPULATIONS OF SIX GROUNDNUT (Arachis hypogaea L.) CROSSES"** submitted to The **Acharya N.G. Ranga Agricultural University** for the degree of **Master of Science in Agriculture** is the result of original research work done by me. I also declare that no material contained in this thesis has been published earlier in any manner.

Place :

Date :

(ANJU MARIAM JOSEPH)
TAM/2009-25

CERTIFICATE

This is to certify that **Miss. ANJU MARIAM JOSEPH** has satisfactorily prosecuted the course of research and that the thesis entitled "**GENETIC STUDIES IN F_2 POPULATIONS OF SIX GROUNDNUT (*Arachis hypogaea* L.) CROSSES"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part there of has not been previously submitted by her for a degree of any university.

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Place:

(Dr. R. P. VASANTHI)
Chairman person

CERTIFICATE

This is to certify that the thesis entitled "**GENETIC STUDIES IN F_2 POPULATIONS OF SIX GROUNDNUT (*Arachis hypogaea* L.) CROSSES**" submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** of the Acharya N.G. Ranga Agricultural University, Hyderabad, is a record of the bonafide original research work carried out by **Miss. ANJU MARIAM JOSEPH** under our guidance and supervision.

No part of the thesis has been submitted for any other degree or diploma. The published part and all assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

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Anju Mariam Joseph....

LIST OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Per cent
°C	:	Degree celsius
ANOVA	:	Analysis of Variance
CD	:	Critical difference
CD (P=0.05%)	:	Critical Difference at 5 percent level
cm	:	Centimetre
DAS	:	Days after sowing
e.g.	:	for example, for instance
et al.	:	Co-workers
etc.	:	and so on; and other people / things
Fig.	:	Figure
g	:	Gram (s)
GA	:	Genetic advance
GAM	:	Genetic Advance as per cent of Mean
GCV	:	Genotypic Co-efficient of Variation
H	:	Heritability in Broad sense
h	:	Hour(s)
ha	:	Hectare
i.e.,	:	That is
kg	:	Kilogram
M ha	:	Million hectares
mm	:	Millimetre
No.	:	Number
PCV	:	Phenotypic Co-efficient of Variation
per se	:	As such with mean
pH	:	Power of hydrogen ion concentration
r	:	Correlation Co-efficient
RAPD	:	Random Amplified Polymorphic DNA
RBD	:	Randomized Block Design
SD	:	Standard Deviation
SEm	:	Standard Error of Mean
Sp. or Spp.	:	Species (singular or plural form)
viz.	:	Namely
vs.	:	Against
X	:	Grand mean

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ABSTRACT

The experimental material used in the study consisted of six segregating populations in F_2 and seven parents. The F_2 populations were derived from six crosses i.e., Tirupati-1 x GPBD-4, Narayani x GPBD-4, Abhaya x GPBD-4, Kadiri-6 x GPBD-4, TLG-45 x GPBD-4 and TCGS-876 x GPBD-4. The material was grown in dry land farm of Regional Agricultural Research Station (RARS), Tirupati during *kharif*, 2010 in a randomized block design with three replications. The data recorded on yield and its component characters and disease resistance component characters were analyzed for variability, heritability, genetic advance, character association and inheritance studies. Mean values, in respect of pod yield, mature pods per plant, harvest index and number of primary branches were high in TLG-45 x GPBD-4, TCGS-876 x GPBD-4 and Abhaya x GPBD-4. Shelling out-turn was high in crosses Tirupati-1 x GPBD-4, Kadiri-6 x GPBD-4 and TCGS-876 x GPBD-4.

With regard to foliar disease resistance parameters, lower mean values in respect of percentage of leaves affected by LLS, rust and LLS and rust severity were recorded in TLG-45 x GPBD-4, TCGS-876 x GPBD-4 and Abhaya x GPBD-4 and higher mean latent period was also registered in these three crosses.

Genotypic coefficient of variation, heritability and genetic advance as percentage of the mean were relatively high for pod yield, mature pods per plant, immature pods per plant and primary branches per plant in four crosses, Abhaya

x GPBD-4, TLG-45 x GPBD-4, Narayani x GPBD-4 and TCGS-876 x GPBD-4. For harvest index, moderate values of GCV, heritability and GAM were recorded in only one cross, TCGS-876 x GPBD-4. In these crosses, these characters appear to be highly influenced by additive gene action. Hence simple phenotypic selection would be effective for the improvement of these traits. In the cross, TLG-45 x GPBD-4, higher values of GCV, heritability and GAM were recorded for latent period. For LLS and rust severity, genetic parameters were high in Tirupati 1 x GPBD-4 and Narayani x GPBD-4 in which female parents were highly susceptible to LLS and rust. In these crosses, selection for disease resistance would be effective in early generations. In Abhaya x GPBD-4, selection for LLS resistance would be more fruitful in early generations. Considerable variation was observed for percentage of leaves affected by rust in five crosses except in TCGS-876 x GPBD-4.

In majority of the crosses, there was significant positive association of pod yield with harvest index, mature pods per plant and latent period and negative significant association with percent of leaves affected by LLS, rust and severity of LLS and rust. Abhaya x GPBD-4 showed non-significant negative association with percent of leaves affected by LLS and rust. The association of pod yield with LLS and rust severity was negative and non significant in the crosses, TLG-45 x GPBD-4 and TCGS-876 x GPBD-4. Harvest index showed a positive significant association with mature pods per plant and shelling out-turn. Changes both in sign and intensity of correlation among characters were found in some of the F_2 populations *i.e.,* between pod yield and shelling out-turn in Narayani x GPBD-4, between mature pods and LLS severity in Abhaya x GPBD-4, indicating the disruption of linkage between characters resulting in new recombinations.

From preliminary studies on inheritance of LLS resistance, it was found to be governed by two genes which exhibit coupling phase linkage in all the crosses. Studies on inheritance of resistance to rust in three crosses indicated the involvement of two genes with duplicate gene action.

From an overall examination, Abhaya x GPBD-4, TLG-45 x GPBD-4 and TCGS-876 x GPBD-4 appear to be best combinations which would throw up desirable segregants in later generations for most of the characters including yield and yield attributes and disease resistance components. These crosses should be studied in greater detail for isolating desirable recombinants in later generations.

Chapter ~ I

Introduction

Chapter I

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) also known as peanut is an important oilseed crop in tropical and subtropical regions of the world. It is a self pollinated crop with a chromosome number, $2n = 4x = 40$. In our country, it is cultivated in an area of 6.16 M ha with a production of 7.17 M t and productivity of 1164 kg ha^{-1}(Annul Report, 2008-2009). In Andhra Pradesh, 1.77 M ha area is under groundnut cultivation with a production of 1.55 M t (2008-2009) and average productivity of 876 kg ha^{-1}. Out of 1.77 million ha, about 80% of the groundnut area comprising 1.5 M ha is under rainfed cultivation during *kharif* season in drylands. Yield of rainfed groundnut is largely dependent on the rainfall pattern during the season. Thus, *kharif* yields vary from 550-1400 kg ha^{-1}.

Groundnut seed is an important source of oil (44-50%), dietary protein (25%) and carbohydrate (20%). Groundnut haulms are excellent fodder and cake is used for animal feed. Plant roots left behind after harvest add valuable nutrients to the soil, which is particularly important in the less developed countries where crop is mainly grown under low input condition.

The cultivated tetraploid groundnut is member of genus *Arachis* and belongs to the family *Leguminosae*, subfamily *Fabaceae*, tribe *Aeschynomeneae*, subtribe *Stylosanthenae*. Based on the differences in the branching pattern and presence of reproductive nodes on the main stem, the species has been classified into two subspecies, *hypogaea* and *fastigiata*. Further each subspecies has been divided into two botanical varieties *viz.* subsp. *hypogaea* into var. *hypogaea* (virginia) and var. *hirsuta* and subsp. *fastigiata* into var. *fastigiata* (valencia), var. *vulgaris* (spanish), var. *peruviana* and var. *aequatoriana*.

Arachis hypogaea is believed to have originated through hybridization of two diploid wild species (*A. duranensis and A. ipaensis*) followed by rare spontaneous duplication of the chromosomes in South America. The resultant allotetraploid plant would have had hybrid vigour but reproductively isolated from wild relatives. Therefore, all land races of groundnut are probably derived from one or a few plants and consequently there exists low diversity for traits of agricultural interest resulting in narrow genetic base of the cultivars, constraining progress of the crop improvement at conventional and molecular level. Paradoxically, the wild diploid *Arachis* species are genetically very diverse and have been selected during evolution by a range of abiotic and biotic stresses, providing a rich source of variation in agronomically important traits; but sterility barriers have hampered the use of wild species in breeding.

The low productivity of the crop in India is ascribed to many biotic and abiotic stresses in the cultivation of the crop. Drought is the single most important abiotic stress factor affecting the yield of rainfed crop besides biotic stresses. Among the biotic stresses, the two major foliar diseases *viz.*, late leaf spot (*Phaeoisariopsis personata* [(Berk. and Curt.) Deighton] and rust (*Puccinia arachidis* Speg.) are widespread and economically most important. They often occur together and cause yield loss up to 50-70 per cent in the crop (Subrahmaniyam *et al.*, 1995). Besides adversely affecting the pod yield and its quality, they affect the yield and quality of haulms. Though several effective fungicides are available to control the diseases, development of resistant cultivars is considered the best strategy to surmount additional cost of production and hazardous effect of fungicides on the soil and environment.

Identification of resistant and susceptible lines from the different sources of gene pools is difficult through conventional screening techniques because of their co-occurrence and defoliating nature of late leaf spot. A high level of resistance to these diseases has been transferred from wild species to cultivars but the conventional breeding has failed in combining resistance with high yield potential and other desirable agronomic traits. Resistant sources often suffer from undesirable traits like low productivity, long duration and poor adaptability besides poor pod and seed traits like thick shell and low shelling percentage. The complex nature of inheritance of resistance governed by recessive genes has hindered the progress of disease resistance breeding.

In the present study, it has been planned to get comprehensive information on genetics of late leaf spot and rust resistance, morphological traits, yield and yield attributes so that it would be useful to the breeder in the development of early maturing, high yielding, foliar disease resistant cultivars with acceptable agronomic attributes in a more precise way. Hence, the present study has been planned with the following broad objectives.

1. To estimate the genetic variability in the F_2 populations of six crosses for late leaf spot and rust resistance, morphological traits, yield and yield attributes.

2. To elicit information on the extent of the correlation between late leaf spot and rust resistance and yield and yield attributes in F_2 populations of six crosses.

3. To study the inheritance of late leaf spot and rust resistance.

Chapter ~ II

Review of literature

Chapter II

REVIEW OF LITERATURE

Hybridization followed by selection in the segregating generations is the main mode of varietal development in self pollinated crops like groundnut. The success of any breeding programme depends upon the amount of variability present for different characters in a population and its efficient management. The genetic coefficient of variation is a useful measure of the magnitude of genetic variance present in the population.

Estimation of genetic variability alone cannot indicate the possible improvement that could be achieved through selection, but it should be used in conjunction with heritability and genetic advance.

The degree of success depends upon the magnitude of heritability as it measures the relative amount of the heritable portion of variability. Genetic advance (GA) under selection gives an idea about how much of genetic gain obtained was due to selection. Hence the estimates of genetic variability, heritability and genetic advance have an immense value in making decisions about the selection methods to be employed to bring about improvement in the desirable traits and yield.

Correlation studies provide better understanding of relationship between yield and its components which helps the plant breeder during selection. The genetic improvement in dependent trait can be achieved by applying strong selection to a character which is genetically correlated with the dependent character. If a character has low heritability, another character having high heritability and high correlation with the former trait can be chosen to make selection more effective.

Loss due to diseases can be controlled cost effectively by resistant varieties. It is essential to know the number of genes controlling resistance these diseases and their inheritance pattern to develop such varieties.

In the present chapter, the literature has been reviewed under the following sub-heads to correlate the results of the present study with the results of earlier workers.

2.1 VARIABILITY, HERITABILITY AND GENETIC ADVANCE

2.2 CHARACTERASSOCIATION

2.3 INHERITANCE STUDIES

2.1 VARIABILITY, HERITABILITY AND GENETIC ADVANCE

Lin (1966) reported that the major portion of genetic variance among F_2 and F_3 progenies of Spanish and Virginia crosses was due to dominance effects for number of pods and pod yield, while additive effects were most important for main stem length and length of branches.

The studies on heritability estimates of some quantitative characters in F_2 populations of J 11 x Gujarat narrow leaf mutant cross by Balaiah and Reddy (1975) showed a high range of heritability (71.7 to 95.1%) for number of mature pods per plant and pod yield per plant. The high heritability estimates along with moderate to high coefficients of variability for above characters indicated that selection for number of mature pods and pod yield in the early segregating generations would be effective.

Patra (1975) studied genetic variability in 35 groundnut crosses and reported high broad sense heritability estimates and expected genetic gain for yield per plant indicating substantial genetic variability in F_2 generation.

Sandhu and Khehra (1976) reported high heritability in broad sense for number of primary branches, number of mature pods and pod yield in their study in C-501 x Ah-6595 and C-501 X AK-12-24 in early generations. Sandhu and Khehra (1977) determined heritability and genetic advance in the F_3 progenies of two peanut crosses for resistance to leaf spot, pod yield, 100-kernal weight, oil and protein contents. Broad sense estimates of heritability were high for all traits except yield in both the crosses. The estimated genetic advance from selection was high only for resistance to leaf spot.

Cahaner (1978) analysed F_2 generation of a diallel set of crosses, F_4, the first DC_1 and second DC_2 generations of the double crosses involving 4 groundnut cultivars *viz*., Shulamith, Line-203, 'Congo' and 'Chico' and reported high heritability of 80 percent for pod weight among all the traits studied.

Mohammed *et al*. (1978) estimated heritability for yield, fruit size and maturity in the F_2 and F_3 generations of two crosses between a Virginia and two Spanish lines. Broad sense heritability estimates based on within plot variance for yield were high ranging from 0.42 to 0.82 for four location environments.

Hari Singh *et al.* (1982) from studies on genetic variability and heritability for morpho-physiological attributes in groundnut reported significant difference among genotypes and high range of variability for biological yield, number of undeveloped pods, harvest index, number of pods per plant and pod yield. The differences between phenotypic and genotypic variances were high for biological yield. Harvest index and pod yield had low heritability values.

Chiow and Wynne (1983) reported substantial genetic variability for yield in advanced generations of a cross between an early maturing Spanish and large fruited Virginia type.

Xiang *et al.* (1984) reported high heritability for the total number of branches in a study of an incomplete diallel of four Spanish and four Valencia lines and suggested that it could be used as an indirect selection criterion for yield in early generations.

Studies of Bhagat *et al.* (1986) revealed high heritability and genetic advance for pod yield per plant and shelling percentage. Kandaswamy *et al*. (1986) reported high heritability estimates for number of primary branches while number of mature pods, shelling percentage, harvest index and pod yield showed moderate heritability estimates. Pod yield recorded high GCV. The study of Kuriakose and Joseph (1986) on 26 groundnut varieties showed that number of primary branches had high heritability and genetic advance.

Reddi *et al*. (1986) conducted studies on variability, heritability and genetic advance in Virginia cultivars of groundnut. They observed considerable amount of phenotypic and genotypic variability for number of primary branches. They obtained low heritability values for harvest index and pod yield and concluded that these traits were under the influence of environmental factors.

Naidu *et al.* (1987) from his studies reported high GCV, PCV, heritability and genetic advance for number of mature pods, number of primaries and pod yield in both parents and back cross progenies. High heritability and low genetic advance were recorded for shelling percentage.

Reddy *et al*. (1987) in 6 x 6 diallel study of groundnut observed high heritability and genetic advance for the height of the main axis, number of primary branches, kernel yield and pod yield whereas high heritability and moderate genetic advance for shelling percentage.

Manoharan *et al*. (1990a) recorded high heritability combined with high genetic advance for pod weight, dry matter production and kernel weight in F_2 population of J11 x Chico. Further, dry matter production exhibited highest (47.8%) genotypic coefficient of variation. Dry matter production, pod weight and pod yield were highly heritable.

Ahamed (1995) reported that heritability, genotypic and phenotypic coefficientsof variation were moderate to high for characters like pod yield per plant, kernel yield per plant, days to maturity and shelling percentage in parents. But they were low to moderate in crosses.

Ganesan and Sudhakar (1995) in their variability studies indicated that primary branches had higher genetic variability coupled with higher heritability and genetic advance. Pod yield per plant showed moderate values of variability but higher heritability coupled with high genetic advance. Mature pods per plant showed moderate values of GCV, heritability and genetic advance.

Sumathi and Ramanathan (1995a) from a study in 30 selected lines from F_2 generation of five crosses reported high heritability estimates for number of mature pods (57.6%), pod yield (57.7%) and shelling out-turn (56.6%).

Varman and Raveendran (1996) observed high heritability for number of mature pods per plant (59.6%), pod yield per plant (55.3%) and oil percent (81.4%) in F_2 population of six crosses. They also reported high heritability and low genetic advance for oil percent indicating contribution of non-additive gene action. High heritability and genetic advance for pod yield per plant and number of mature pods per plant were obtained indicating the role of additive gene action in the inheritance of these characters.

Jayalakshmi (1997) reported that among morphological and physiological attributes studied at population level, high genotypic coefficient of variation and heritability were observed for harvest index and root dry mass in segregating generations. Yield and yield attributes exhibited high heritability in F_3 generation.

Jayalakshmi *et al.* (1998) in their studies on F_4 progenies of eight crosses of groundnut observed significant difference for four attributes *viz.*, specific leaf area, total dry matter, pod weight per plant and harvest index. The cross, ICGV-86031 x JL-24 was found to be superior for harvest index. Two crosses, TAG-24 x TPT-1 and TG-26 x JL-24 displayed high heritability and greater genetic advance for pod weight.

Rudraswamy *et al.* (1999) observed moderate genetic advance and high heritability for number of immature pods per plant, pod yield per plant and shelling percentage in parents, F_1, F_2 and F_3 generations of six crosses of groundnut. Singh and Singh (1999) reported high heritability values for plant height, primary branches, pod yield per plant, shelling percentage and 100-kernel weight.

Naik *et al*. (2000) observed high GCV for pod weight per plant, 100-kernel weight and plant height suggesting that selection for these characters would be more effective. In their study, GCV was found to be low for number of primaries per plant, number of pods per plant, shelling percentage and sound mature kernel percentage. High heritability for 100-kernel weight and number of primary branches was recorded. They recorded moderate heritability values for plant height and pod weight per plant and high genetic advance as percentage of mean for pod weight per plant and 100-kernel weight.

Rostini *et al*. (2000) reported high GCV, PCV, heritability and genetic advance as per cent of mean for harvest index, 100 seed weight, kernel yield per plant and shelling percentage. The low estimates of variability, heritability and genetic advance were observed for primary branches per plant, days to maturity, plant height, pods per plant, mature pods per plant and oil content.

Vasanthi and Raja Reddy (2002) in their study in five F_2 populations reported high heritability for shell thickness. Moderate to high heritability coupled with moderate to high genetic advance were reported for pod and kernel yield per plant.

Kumar and Rajamani (2004) observed high GCV and PCV values for seed yield, 100-kernel weight, sound mature kernel per cent, moderate PCV and GCV values for shelling per cent and low values for days to maturity. They also observed high heritability coupled with high genetic advance for yield, 100-kernel weight and sound mature kernel per cent.

Seethala Devi (2004) from the analysis of estimates of genetic parameters in F_2 population of 10 groundnut crosses reported that pod yield per plant, kernel yield per plant and harvest index exhibited moderate to high heritability and genetic advance as per cent of mean and hence, are governed by additive gene action and fixable in early generations with simple selection methods.

Parameshwarappa *et al*. (2005) indicated higher genetic variability for number of primary branches, pod yield per plant, kernel yield and plant height. Variability observed for oil content and sound mature kernels was low. High heritability coupled with genetic advance was noticed in respect of kernel yield, sound mature kernels and 100-kemel weight indicating that additive genes govern these characters. The extent of genetic advance was quite low for kernel size, protein content and oil content indicating that these traits are influenced by environment.

Suneetha *et al*. (2005) reported high heritability coupled with high genetic advance as per cent of mean for number of mature pods and number of immature pods, high heritability coupled with moderate genetic advance as per cent of mean for days to 50 per cent flowering and height of the main axis, 100-seed weight and pod yield per plant. Number of primary branches and shelling percentage registered high heritability coupled with low genetic advance as per cent of mean.

John *et al*. (2008) studied segregating populations in groundnut and observed that GCV and PCV values were high for number of secondary branches per plant, pod yield per plant, kernel yield per plant and jassid incidence. Moderate GCV and PCV were observed for shelling out-turn and 100- kernel weight. Low values of GCV and PCV were recorded for days to initial flowering, days to maturity, number of primary branches, SCMR, late leaf spot and rust. All the characters showed high heritability values ranging from 66.67 % to 99.50%. High heritability along with high GAM were obtained for number of secondary branches per plant, shelling out-turn, kernel yield per plant and 100- kernel weight, indicated the importance of additive gene action.

Giri *et al.* (2009) observed high estimates of PCV, GCV, heritability and genetic advance as per cent of mean for late leaf spot disease severity, reducing sugar, kernel yield per plant and pod yield per plant. It indicated the role of additive gene action.

Khote *et al.* (2009) studied the performance, genetic variability, heritability and genetic advance for yield and yield contributing characters of 30 exotic groundnut genotypes. Higher phenotypic and genotypic coefficients of variations were observed for pods/plant, pod length, number of kernels/plant, kernel yield/plant, fodder/plant, harvest index and pod yield/plant. Characters like days to flowering, pod length, kernel length, 100-pod weight and dry matter/plant showed high heritability. The highest genetic advance as percentage of mean was recorded for kernel yield/plant, fodder/plant, harvest index and pod yield/plant.

Raut *et al.* (2010a) evaluated six crosses in F_2 generation. Analysis of variance revealed highly significant differences among the genotypes, parents as well as crosses for all the characters indicating sufficient variability in the material studied. 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. All the characters expressed high heritability estimates except shelling out-turn in two crosses.

Shinde *et al.* (2010) from a study on fifty elite genotypes of virginia bunch groundnut reported higher GCV and PCV estimates for pod yield per plant, number of immature pods per plant, number of mature pods per plant and biological yield per plant indicating large extent of genetic variability for these parameters. High heritability was associated with high genetic advance and high GCV for pod yield per plant and number of mature pods per plant.

2.2 CHARACTER ASSOCIATION

Hassan and Beute (1977) concluded that a visual estimate of percentage of leaves with leaf spots was an efficient evaluation method when large numbers of entries are to be tested for resistance to foliar diseases. There exists a significant negative correlation.

Sandhu and Khehra (1977) reported that pod yield was closely correlated with number of primary branches, length of primary branches and secondary branches in F_3 generation of C-501 x Ah-6595.

High positive association of pod yield with number of mature pods was observed by Labana *et al.* (1980). They also reported that height of main shoot, the number of primary branches and pods were significantly correlated with one another. Nagabhushanam *et al.* (1982a) reported that yield in groundnut was positively and significantly correlated with the number of primary branches and shelling out turn, while it was negatively correlated with height of main axis.

Nigam *et al.* (1984) studied ninety-seven advanced generation selections derived from inter sub-specific and intra sub-specific crosses for the association among sixteen vegetative and reproductive traits. Weight per mature seed showed significant positive association with most of the vegetative traits and mature pods per plant, mature pod weight, mature seed per plant, and mature seed weight with height of the main axis and nodes with pegs.

Bhagat *et al.* (1986) reported that pod yield had a significant positive phenotypic correlation with number of mature pods and shelling percentage. Number of primary primary branches had non- significant correlation with pod yield. Kuriakose and Joseph (1986) showed that primary branches were positively correlated with pod yield.

Studies of Gupta (1987) indicated positive and significant association of kernel yield with shelling per cent and pod yield. Shelling percentage and number of mature pods showed strong association with pod yield.

Iroume and Knauft (1987) noted negative correlations between yield and leaf spot severity from 11 crosses chosen in the S_1 (first selfed generation) on the basis of yield and disease reaction. The expected progress in increasing resistance of peanut genotypes through selection for yield (30-40% of the response from direct selection for resistance) indicated that evaluation for yield under disease pressure may be advantageous for developing high yielding, leaf spot tolerant genotypes.

Mishra and Yadava (1992) in a correlation study on 20 groundnut varieties observed that kernel yield was positively and significantly associated with dry pod yield. Vaddoria and Patel (1992) noticed that pod yield in Virginia runner type was significantly correlated with harvest index, shelling per cent, number of mature pods per plant, 100-seed weight and number of primary branches per plant.

Pushkaran and Nair (1993) reported that pod yield was significantly and positively correlated with haulm yield, number of mature pods and number of immature pods. They also observed significant positive association of pod yield with number of mature pods and number of mature pods with shelling percentage.

Singh and Singh (1999) indicated that yield improvement could be achieved by selection for days to 50 per cent flowering, plant height, number of branches, number and weight of pods per plant and kernel weight.

Azad and Hamid (2000) studied the character association and path coefficients in nine breeding lines of groundnut together with their parent variety. Pod number, kernel yield and 100-pod weight demonstrated mostly significant positive genotypic and phenotypic correlation with pod yield. In contrast, the remaining five characters showed negative relationship.

Johar Singh and Mohinder Singh (2001) studied correlation in five advanced lines and eight segregating populations of two crosses. They observed that number of pods had the significant positive association with pod yield per plant. Positive association of harvest index with pod yield per plant and sound mature kernel per cent was also obtained.

Vijayasekhar (2002) reported that pod yield per plant registered highly significant positive association with kernel yield per plant, harvest index and pods per plant.

Seethala Devi (2004) reported significant positive association of kernel yield per plant, harvest index and sound mature kernel per cent with pod yield per plant in parents and F_2 populations.

Parameshwarappa *et al*. (2005) indicated that pod yield had positive and significant association with shelling per cent, sound mature kernels, 100-kemel weight and oil content while the association was negative with protein content among 48 diverse large seeded groundnut genotypes. Among yield traits, number of pods exhibited positive association with shelling per cent, sound mature kernels and oil content. Sound mature kernels percent was found to be positively associated with higher kernel weight.

John *et al*. (2005) studied correlations in four single crosses and their parents (JL-24, TCGS-150, R-8808 and ICGV-88083). They reported highly significant and positive correlation of pod yield with number of secondary branches, number of mature pods, kernel yield, pod length, haulm weight and harvest index.

Joel *et al.* (2006) in their study on twelve crosses indicated that the incubation period and number of functional leaves exhibited positive and significant correlation with pod yield.

Cantonwine *et al.* (2008) assessed components of resistance for three runner-type peanut cultivars to infection by *Cercosporidium personatum*, the causal organism of late leaf spot and reported that latent period was found to be two days longer for resistant genotypes.

Giri *et al.* (2009) reported that pod yield showed positive significant association with days to 50 per cent flowering, days to maturity, kernel yield, test weight and oil content, where as negative significant association with late leaf spot disease severity and reducing sugars.

Korat *et al.* (2010) reported positive and significant association of biological yield per plant, 100-kernel weight and harvest index with pod yield per plant at phenotypic level. Genotypic correlations of above said yield components with pod yield were also strong and with similar sign.

Raut *et al.* (2010b) estimated the correlation coefficients among eleven yield and yield contributing traits along with their path effects towards pod yield in F_2 generation of six crosses of groundnut. The correlation coefficients of pod yield per plant were found positive and highly significant with kernel yield per plant, number of mature pods per plant and shelling out-turn.

2.3 INHERITANCE STUDIES

2.3.1. Inheritance of late leaf spot and rust resistance

Bromfield and Bailey (1972) reported digenic control of rust (*Puccinia arachidis* speg.) resistance, with resistance recessive to susceptibility.

Sharief (1972) reported that two or more nuclear genes controlled resistance to leafspot.

Sharief *et al.* (1978) concluded from study of triploid F_1 hybrids of crosses between resistant wild species and susceptible *hypogaea* lines that leafspot (*Cercospora arachidicola* Hori and *Cercosporidium personatum* (Berk & Curt)) resistance was recessive since all hybrids were susceptible

Studies of Nevill (1980) in F_2 of a cross between Robout 33-1 and Krapovickas 16 revealed that genes at three or four loci were controlling the disease reaction (late leaf spot).

Nevill (1982) studied inheritance of resistance to *Cercosporidium personatum* in five F_2 populations from crosses between three resistant lines (*Arachis hypogaea* subsp. *fastigiata* var. *fastigiata*) and three susceptible cultivars (two *Arachis hypogaea* subsp. *fastigiata* var. *vulgaris* and one *Arachis hypogaea* var. *hypogaea*) in which the susceptible material was used as female parent. A genetic system involving 5 loci was proposed to account for the results.

Nigam *et al.* (1980) reported that rust resistance is governed by duplicate recessive genes.

Kornegay *et al*. (1980) proposed that resistance to leaf spots was quantitatively inherited.

Studies of Tiwari *et al.* (1984) indicated that the rust resistance is recessive to susceptibility and controlled in additive fashion. He observed phenotypic ratio of 1 resistant : 6 intermediate : 9 susceptibile , a typical digenic additive ratio.

Jogloy *et al.* (1988) reported that the resistance to late leaf spot and most of the agronomic traits were under the control of additive gene action. They obtained lower estimates of broad-sense heritability for all paramaters of late leaf spot resistance.

Soriano (1988) screened seeds of CES-3 gamma-irradiated with doses of 10-40 kR and M_2 plants for resistance to *Cercospora personata* [*Mycosphaerella berkeleyi*] and *C. arachidicola* [*M. arachidis*]. Five tolerant mutants were obtained. Inheritance studies indicated that resistance is recessive, governed by two duplicate genes.

Paramasivam *et al.* (1990) studied crosses between the rust (*Puccinia arachidis*) susceptible cultivar, Co 2 as female parent and the male parents NCAC17090, PI414331 and PI414332, previously reported to have rust resistance. In the F_2 generation, susceptibility was found to be dominant to resistance. The F_2 population segregated in the ratio of 3 susceptible to 1 resistant with resistance governed by a single recessive gene.

Vindhiya Varman *et al.* (1993) studied F_1 and F_2 generations of crosses of NcAc17090 and NcAc17135, lines resistant to rust [*Puccinia arachidis*], with the susceptible varieties, JL24 and R-33-1. They inferred that rust resistance in groundnut is controlled by two recessive genes.

From studies in F_2 populations of five crosses, Vasanthi and Raja Reddy (1997) inferred that late leaf spot resistance is under the control of four to five duplicate recessive genes while rust resistance is controlled by two to three genes acting in duplicate complementary manner.

Joel *et al.* (2006) studied the genetics of rust resistance in groundnut in twelve crosses selected from 40 crosses of line x tester mating design involving eight resistant and five susceptible genotypes. F_1, F_2, B_1 and B_2 generations were sown in the field and screened for sensitivity for rust following the infector row technique under epiphytotic condition. The study revealed that resistance was recessive and they obtained monogenic (3:1), digenic (15:1) and trigenic (63:1) ratios in F_2 generation. Segregation pattern in B_1 and B_2 generations confirmed that rust resistance is governed by recessive alleles of one to three genes.

Mondal *et al.* (2007) reported that rust resistance is governed by a single dominant gene from a study in F_2 population of 117 individuals derived from a cross between rust resistant VG 9514 (female) and rust susceptible TAG 24 (male). They identified a RAPD marker $J7_{1300}$ linked with rust resistance.

2.3.2. Transgressive segregation in groundnut

Genetic studies indicate that transgressive segregation typically results from recombination between parental taxa that possess quantitative trait loci (QTLs) with antagonistic effects (i.e. QTLs with effects that are in the opposite direction). Plants possess significantly more antagonistic QTLs than animals. Likewise, antagonistic QTLs were more frequent in intra-specific than in inter-specific crosses and in morphological than in physiological traits. These results indicate that transgressive segregation provides a general mechanism for the production of extreme phenotypes at both above and below the species level and testify to the possible creative part of hybridization in adaptive evolution and speciation (Loren Rieseberg *et al.* 2003).

Jayalakshmi (2000) studied frequency of transgressive segregants in 21 crosses in F_2 and F_3 generation for physiological and yield attributes. Cross ICG 2716 × ICGV 86031 exhibited higher frequency of transgressive segregants for majority of the attributes studied in addition to kernel yield. Among others, ICG 2716 × TAG 24, ICG 2716 × TG 26, ICG 86031 × TG 26, TAG 24 × TG 26 × TMV2-NLM had transgressive segregants for kernel yield and other attributes like harvest index and pod number per plant.

Monpara *et al.* (2004) reported that transgressive F_2 plants were observed for traits such as days to flower initiation, plant height, pods per plant, oil content and pod yield per plant, at least, in one direction in six crosses of groundnut. They concluded that parents used in the study have contributed different alleles.

Muhammed Azharudheen (2010) reported a higher percentage of the superior segregants for rust resistance in the cross involving a Virginia parent (TG 19), whereas, the cross involving a Spanish bunch parent (TG 49) revealed high percentage of superior segregants for late leaf spot, productivity and quality traits. The presence of transgressive segregants in both directions indicated contribution of favourable alleles from both the parents.

Chapter ~ III

Material and Methods

Chapter III

MATERIAL AND METHODS

The present investigation was carried out during *kharif* 2010 at Regional Agricultural Research Station, Tirupati situated at an altitude of 182.90 m above MSL, 13^0N latitude and 79^0E longitude. The experimental soil was of sandy clay loam type. The materials used and the methods followed pertaining to the present investigation are presented here under.

3.1 MATERIAL

The experimental material consisted of six F_2 populations, Tirupati 1 x GPBD 4, Narayani x GPBD 4, Abhaya x GPBD 4, Kadiri 6 x GPBD 4, TLG 45 x GPBD 4 and TCGS 876 x GPBD 4 and seven parents , Tirupati 1, Narayani, Abhaya, Kadiri 6, TLG 45, TCGS 876 and GPBD 4. The material was made available by the Principal Scientist (Plant Breeding), Regional Agricultural Research Station, Tirupati. The characteristic features of the parents are as given in Table 3.1.

Table 3.1: Important characteristics of parental genotypes

S No.	Cultivar	Pedigree	Characteristic features
1.	Tirupati 1	Selection from germplasm line EC 106983/3A	Erect growth habit with four primaries, moderate stature, foliage light green, leaflets narrow with whitish ashy coat on both the surfaces, suitable for scarce and low rainfall areas of Andhra Pradesh, also suitable for late sown conditions of rice fallows and coastal sands, highest shelling out turn of 76-79% , SMK – 95%, oil content - 49% (seeds), 100 pod weight - 70-80g, 100 seed weight – 33-36g, pods

			small, two seeded, slightly beaked, reticulated with slight constriction, non-dormant, duration – 100 days
2.	Narayani	JL-24 x Ah316/S	Erect growth habit with 4-5 primaries, leaflets long and large, elliptical and green, stem with light greenish purple pigmentation, suitable for both the seasons, tolerant to mid season moisture stress, synchronous maturity of pods, light red testa, shelling out turn – 75 - 76%, oil content – 49%, pods two seeded, medium bold with moderate reticulation and slight beak, 100 pod weight – 90-100g, 100 kernel weight – 40-45g, duration – 100 days.
3.	Abhaya	K-134 x TAG-24	Short and compact type, pods mostly three-seeded, reticulated with slight beak, leaflets narrow, elliptical and dark green, pods slender and medium bold, testa colour rose, duration - 105-110 days, shelling out-turn - 76-77%, high WUE, drought and LLS tolerant, tolerant to sucking pest and *Spodoptera*. High oil conent (52%).
4.	Kadiri 6	JL-24 x Ah316/S	Erect growth habit, with four primaries, light green leaflets, large and oblong, recommended for *rabi* cultivation, oil content - 48%, pods medium bold, shelling out turn – 72%, duration – 95-100 days, uniform maturity.
5.	TLG 45	TG-19 x TAG-24	Erect with semi-dwarf stature, sequential flowering and dark green leaves, pods mostly two-seeded with medium constriction, medium reticulation and medium to prominent beak, seeds cylindrical in shape with rose coloured testa. Seed contains 49.6% oil, It matures in 115 days with an average 100-seed weight of 60 g and shelling out-turn of 68%, large seeded variety showing moderate tolerance to LLS.

6.	TCGS 876	TCGP6 x Jal 30	Erect growth habit, light green leaves, shelling out turn – 68%, 100 seed weight – 45-47g, duration –105 – 110 days, tolerant to bud necrosis disease and moisture stress.
7.	GPBD 4	KRG-1 x ICGV-86855	Erect growth habit with sequential branching pattern, medium-size wide elliptic, moderately dark green leaves, matures in 105-110 days after sowing in the rainy season, pods medium size with slight reticulation, slight beak, and moderate constriction. pods are two seeded with an average shelling out turn of 76%, seeds are tan and contain 48% oil; the 100-seed mass is 42g, early maturing variety resistant to LLS and rust.

3.2 METHODS

3.2.1 Field Layout

Six F_2 populations and seven parents were sown in randomized block design with three replications on 13th July 2010. The F_2 populations were grown in three rows of 5 m length and parents in two rows of 5 m length in each replication. The parents and the F_2 populations were sown following a spacing of 30 cm between the rows and 10 cm between the plants within a row. To know the behaviour of F_1s with respect to late leaf spot and rust resistance, F_1s were raised in unreplicated plot adjacent to the experimental plot.

3.2.2 Crop husbandry

The field was ploughed and harrowed to a fine tilth. The crop was raised with protective irrigation during *kharif* 2010. The crop was fertilized at 20 kg N, 40 kg P_2O_5 and 50 kg K_2O and 500 kg gypsum ha^{-1} in the form of urea, single super phosphate and muriate of potash respectively. Weeding was carried out twice before 45 DAS during the crop growth period.

3.2.3 Data recording

Data on the following characters were recorded during the course of experimentation. Data were collected on ten randomly selected plants in each replication in each parent and 30 plants in each replication in each F_2 population for yield and yield components and for the entire population for inheritance studies. The details of the data recorded were as follows.

Characters

Biometrical data were collected on the following characters.

3.2.3.1 Plant height (cm)

Height of the plant was measured in centimeters from collar region to the tip of the main axis.

3.2.3.2 Number of primary branches

Number of primary branches was determined at the time of harvest by counting all the branches originating from the main axis.

3.2.3.3 Number of mature pods per plant

Number of well filled and mature pods per plant was counted at the time of harvest.

3.2.3.4 Number of immature pods per plant

Number of immature pods per plant was counted.

3.2.3.5 Shelling out turn (%)

Shelling out turn was calculated using the formula

$$\text{Shelling out turn} = \frac{\text{Kernel yield per plant (g)}}{\text{Pod yield per plant (g)}} \times 100$$

3.2.3.6 Harvest index (%)

Harvest index was calculated by using the formula

$$\text{Harvest index} = \frac{\text{Economic yield per plant (g)}}{\text{Biological yield per plant (g)}} \times 100$$

3.2.3.7 Per cent of leaves affected by late leaf spot

The percentage of leaves affected by late leaf spot (LLS) was calculated at the time of harvest using the following formula

$$\text{Leaves affected by late leaf spot} = \frac{\text{No.of leaves affected by LLS}}{\text{Total no.of leaves}} \times 100$$

3.2.3.8 Per cent of leaves affected by rust

The percentage of leaves affected by rust was calculated at the time of harvest using the following formula

$$\text{Leaves affected by rust} = \frac{\text{No.of leaves affected by rust}}{\text{Total no.of leaves}} \times 100$$

3.2.3.9 Latent period for late leaf spot from inoculation to first appearance of symptom

The period from spraying of spore suspension to the appearance of the first symptom was noted.

3.2.3.10 Late leaf spot incidence (score on 1-9 scale)

Disease scoring for late leaf spot was done on plant basis according to 1-9 scale (Subramanyam, 1982) at 90 days after sowing.

1	-	No disease
2	-	1 to 5% disease severity
3	-	6 to 10%
4	-	11 to 20%
5	-	21 to 30%
6	-	31 to 40%
7	-	41 to 60%
8	-	61 to 80%
9	-	81 to 100%

The scores are classified into 3 groups as given below.

Less susceptible	-	1-3
Moderately susceptible	-	4-6
Highly susceptible	-	7-9

3.2.3.11 Rust incidence (score on 1-9 scale)

Disease scoring for rust was done on plant basis according to 1-9 scale (Subramanyam, 1982) at the time of harvest.

1	-	No disease
2	-	1 to 5% disease severity
3	-	6 to 10%
4	-	11 to 20%
5	-	21 to 30%
6	-	31 to 40%
7	-	41 to 60%
8	-	61 to 80%
9	-	81 to 100%

The scores are classified into 3 groups as given below.

Less susceptible	-	1-3
Moderately susceptible	-	4-6
Highly susceptible	-	7-9

3.2.3.12 Pod yield per plant (g)

Weight of dried matured pods per plant was measured in grams.

Inheritance Studies: For inheritance studies, individual plants in each cross were scored for late leaf spot at 90 days after sowing and rust at the time of harvest. Individuals in each F_2 population were classified as resistant (1-3 score), moderately susceptible (4-6 score) and susceptible

(7-9 score) for both late leaf spot and rust. The segregation pattern was studied using Chi-square analysis.

3.3 STATISTICAL ANALYSIS

The data collected on randomly selected plants in parents and F_2 populations in different replications were averaged and mean values were subjected for analysis of variance to test the significance among F_2 populations and parents. Genetic parameters and character associations were studied cross-wise.

3.3.1 Analysis of Variance: Analysis of variance for parents and F_2 populations were carried out for different characters as per Panse and Sukhatme (1985).

$$Y_{ij} = \mu + g_i + r_j + e_{ij}$$

where,

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

μ = General mean.

g_i = Effect of i^{th} genotype.

r_j = Effect of j^{th} replication.

e_{ij} = Random error associated with i^{th} genotype and j^{th} replication.

The analysis of variance for each character was carried out as indicated below.

Source of variation	**Degree of freedom**	**Sum of squares**	**Mean sum of squares**	**'F' ratio**
Replications	(r-1)	RSS	M_r	M_r / M_e
Treatments	(t-1)	VSS	M_t	M_t / M_e
Error	(r-1) (t-1)	ESS	M_e	
Total	(rt-1)			

where,

r	=	Number of replications
t	=	Number of treatments (genotypes)
M_r	=	Mean sum of squares due to replications
M_t	=	Mean sum of squares due to treatments
M_e	=	Mean sum of squares due to error.

The test of significance was carried out by referring to 'F' table value given by Fisher and Yates (1967).

3.3.2 Estimation of Genetic Parameters

3.3.2.1 Coefficients of Variations: Phenotypic and genotypic coefficients of variation (PCV and GCV) were computed according to the Burton (1952).

Phenotypic variance of F_2 population = σ^2_p

$$\text{Environmental variance} = \frac{\text{Variance of parent 1} + \text{Variance of parent 2}}{2} = \sigma^2_e$$

Genotypic variance (σ^2_g) = $\sigma^2_p - \sigma^2_e$

$$\text{Phenotypic coefficient of variation (\%)} = \frac{\sigma_p}{\text{General mean}} \times 100$$

$$\text{Genotypic coefficient of variation (\%)} = \frac{\sigma_g}{\text{General mean}} \times 100$$

Where σp and σ_g represents the phenotypic standard deviation and genotypic standard deviation respectively.

Categorization of the range of variation was effected as per Stansfield (1969)

Low	:	0-20%
Moderate	:	20-50%
High	:	Above 50%

3.3.2.2 Heritability in Broad Sense [h^2(b)]: Heritability in broad sense was estimated using the formula of Allard (1960).

$$\text{Heritability } [h^2(b)] = \frac{\text{Genotypic variance } (\sigma^2_g)}{\text{Phenotypic variance } (\sigma^2_p)} \times 100$$

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

Low	:	0-30%
Moderate	:	30-60%
High	:	Above 60%

3.3.2.3 Genetic Advance (GA): This is calculated as per the formula suggested by Johnson *et al.* (1955).

$$GA = \sigma_p \times H \times k$$

where,

σ_p	=	Phenotypic standard deviation
H	=	Heritability in broad sense
K	=	Selection differential at 5% selection intensity (2.06)

3.3.2.4 Genetic Advance as Percent of Mean (GAM):

$$GAM = \frac{\text{Genetic advance}}{\text{Grand mean}} \times 100$$

The range of genetic advance as percent of mean (GAM) classified by Johnson *et al.* (1955) is given below.

Low	:	0 – 10%
Moderate	:	10 - 20%
High	:	above 20%

3.3.3 Character Association: Phenotypic correlation coefficients were estimated as per the method given by Johnson *et al.* (1955). The correlation coefficients were calculated for individual crosses and individual parents to get the information how the associations in parents have changed in crosses.

$$r_p(xy) = \frac{Cov_p(xy)}{(V_P x)^{1/2} (V_P y)^{1/2}}$$

where,

$r_p(xy)$ = Phenotypic correlation coefficient between x & y characters

$Cov_p(xy)$ = Phenotypic covariance between x & y characters

$(V_P x)$ = Phenotypic variance of x characters

$(V_P y)$ = Phenotypic variance of y characters

The significance of correlation coefficients was tested by comparing the observed value of correlation coefficients with table value of correlation coefficients given by Fisher and Yates (1963) for n - 2 degrees of freedom.

3.3.4 χ^2 Test: For testing the goodness of fit of the segregation pattern to different genetic ratios for late leaf spot and rust resistance, Chi square test was conducted.

$$\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e}$$

where,

$\sum$ = Summation notation

f_o = Observed frequency

f_e = Expected frequency

Fig 3.1 Layout of experimental field

Chapter ~ IV

Results and Discussion

Chapter IV

RESULTS AND DISCUSSION

Breeders of self pollinated crops like groundnut mostly rely on hybridization followed by selection in segregating generations to combine traits of interest *i.e.* insect or disease resistance or earliness or drought resistance with high yield potential. This is mostly achieved by attempting crosses between already adapted varieties which lack one or two traits like disease resistance or to bring in desirable alleles with respect to different traits from unadapted germplasm to increase genetic variability. The effectiveness of selection is dependent upon the nature, extent and magnitude of genetic variability present in material and the extent to which it is heritable.

4.1 ANALYSIS OF VARIANCE IN SEGREGATING POPULATIONS (F_2) AND PARENTS

ANOVA for 12 characters of the six crosses and seven parents revealed significant differences for plant height, primary branches per plant, mature pods per plant, immature pods per plant, shelling out-turn, harvest index, percent of leaves affected by LLS, percent of leaves affected by rust, latent period, LLS score at 90 DAS (1-9 scale), rust score at harvest (1-9 scale) at both the levels of significance and pod weight per plant at 5 percent level of significance. (Appendix). ANOVA is carried out for testing the significance between the F_2 populations (Mohammed *et al.,* 1978)

4.2 MEAN PERFORMANCE OF PARENTS AND F_2 POPULATIONS

4.2.1 Plant Height (cm): Plant height in parents varied from 23.47 cm (TLG 45) to 49.67 cm (Narayani) (Table 4.1). Among parents, plant height was higher in Narayani (49.67 cm), Kadiri-6 (45.33 cm) and Tirupati 1 (41.47 cm). The mean height of the parents was 38.41 cm. The mean of F_2 populations was

Table 4.1.Mean performance of parents and F_2 populations of six crosses for 12 characters in groundnut

	Plant height	Primary branches	Mature pods	Immature pods	Shelling out-turn	Harvest index	LLS affected leaves (%)	Rust affected leaves (%)	Latent period	LLS Score	Rust Score	Pod yield
Parents												
Tirupati-1	41.47	4.07	8.63	6.07	64.81	35.53	94.07	78.03	1.47	7.63	2.63	5.53
Narayani	49.67	4.10	6.90	4.30	66.86	32.84	95.63	85.33	1.20	8.17	2.20	5.03
Abhaya	33.30	4.13	10.87	3.70	65.43	44.02	80.03	48.33	1.67	7.03	1.87	7.78
Kadiri-6	45.33	4.13	7.00	2.80	67.71	37.30	95.33	82.27	1.23	7.67	2.77	5.66
TLG-45	23.47	4.03	8.73	10.73	68.45	50.17	77.83	42.23	1.50	6.70	1.70	7.65
TCGS-876	38.87	4.77	9.83	3.33	64.88	41.86	66.70	54.77	1.70	6.77	2.07	7.86
GPBD-4	36.73	4.37	10.97	2.60	48.97	25.80	43.10	14.97	5.53	5.37	1.97	4.91
Crosses												
Tirupati-1 x GPBD-4	43.43	4.39	9.70	3.24	63.32	27.16	92.19	77.66	1.47	7.46	2.47	4.86
Narayani x GPBD-4	53.59	4.33	8.86	3.76	59.54	25.26	90.43	74.16	1.36	7.78	4.42	5.12
Abhaya x GPBD-4	38.50	4.20	10.80	4.72	56.01	27.71	89.47	62.41	1.71	7.28	1.97	6.06
Kadiri-6 x GPBD-4	41.66	4.26	7.69	3.29	65.89	30.16	95.98	75.50	1.33	7.57	2.53	4.62
TLG-45 x GPBD-4	35.24	4.44	11.26	6.99	57.73	37.73	79.92	61.20	1.97	7.27	2.13	7.06
TCGS-876 x GPBD-4	47.92	4.56	9.82	4.18	60.17	31.76	80.18	55.08	1.64	7.00	2.28	6.47
Mean of												
Parents	38.41	4.23	8.99	4.79	63.87	38.22	78.96	57.99	2.04	7.05	2.17	6.35
Crosses	43.39	4.36	9.69	4.36	60.44	29.96	88.03	67.67	1.58	7.39	2.63	5.70
CD at												
P = 0.05	6.227	0.29	2.179	1.627	4.884	7.770	3.619	8.362	0.323	0.574	0.530	2.045
P = 0.01	8.437	0.40	2.952	2.204	6.618	10.528	4.904	11.329	0.437	0.778	0.718	NS

43.39 cm with a range from 35.24 cm (TLG 45 x GPBD 4) to 53.59 cm (Narayani X GPBD 4). F_2 means exceeded better parent plant height mean in all the cross combinations except in the cross, Kadiri-6 x GPBD-4 where it was lower than the better parent. This might be due to favourable combination of alleles governing plant height.

4.2.2 Primary Branches per Plant: Higher number of primary branches per plant was observed in TCGS 876 (4.77) where as it was lower in TLG 45 (4.03) with a general mean of parents being 4.23. The parents, TCGS 876 (4.77) and GPBD 4 (4.37) possessed higher number of primary branches per plant. The range among F_2 populations was between 4.20 (Kadiri 6 x GPBD 4) and 4.56 (TCGS 876 x GPBD 4). F_2 means were intermediate between the parents involved in a particular cross and towards GPBD-4 *i.e.* higher than the female parents involved indicating incomplete dominance of higher number of primary branches over lower number of primary branches.

4.2.3 Mature Pods per Plant: The number of mature pods in parents ranged from 10.97 (GPBD 4) to 6.90 (Narayani) with a general mean of 8.99. The parents, GPBD 4 (10.97) and Abhaya (10.87) possessed the highest number of mature pods per plant. The mean observed in the F_2 population was 9.69 and the values varied from 7.69 (Kadiri-6 x GPBD 4) to 11.26 (TLG-45 x GPBD 4). F_2 means were mostly in between the parents involved and towards the parent with higher number of mature pods per plant *i.e.* GPBD-4. In the cross Abhaya x GPBD-4, the means of parents Abhaya, GPBD-4 and F_2 means were 10.87, 10.97 and 10.8 respectively. This could be due to presence of similar alleles in both the parents influencing mature pods per plant.

4.2.4 Immature Pods per Plant: The mean number of immature pods per plant in the parents was 4.79. The number of immature pods per plant varied from 2.60 (GPBD-4) to 10.73 (TLG-45). In the F_2 population, these ranged from 3.24 (Tirupati-1 x GPBD-4) to 6.99 (TLG-45 x GPBD-4). The mean number of immature pods per plant of the crosses was 4.36. Number of immature pods per plant was lower in F_2 populations in comparison with parents which is conspicuous in cross combination, TCGS-876 x GPBD-4.

4.2.5 Shelling Out-turn (percent): The higher shelling out-turn among the parents was recorded by TLG-45 (68.45) and Kadiri-6 (67.71) and it was lower in GPBD-4 (48.97). The mean shelling out-turn of the parents was 63.87. The mean shelling out-turn of F_2 was 60.44. The shelling out-turn in F_2 populations ranged from 56.01 (Abhaya x GPBD-4) to 65.89 (Kadiri-6 x GPBD-4). Mean shelling out-turn was lower in F_2 populations in comparison with parents.

4.2.6 Harvest Index (percent): The mean harvest index of the F_2 population was 29.96. It was higher in TLG-45 x GPBD-4 (37.73) and lower in Narayani x GPBD-4 (25.26). The general mean of the parents was 38.22. The harvest index was higher in TLG-45 (50.17) and lower in GPBD-4 (25.80) among parents. Harvest index in F_2 populations was lower than their corresponding parents in all the cross combinations.

4.2.7 LLS Affected Leaves (%): The highest percent leaves affected by LLS among parents was observed in Narayani (95.63) followed by Kadiri-6 (95.33) and Tirupati-1 (94.07). The lowest value was recorded by GPBD-4 (43.10). The general mean value for parents was 78.96. In F_2 populations, it ranged from 79.92 (TLG-45 x TCGS-876) to 95.98 (Kadiri-6 x GPBD-4) and the mean was 88.03. Percent of leaves affected by LLS in F_2 populations was lower than the susceptible parent involved but very high in comparison with the resistant parent, GPBD-4 *i.e.* F_2 means were more towards susceptibility.

4.2.8 Rust Affected Leaves (%): The mean of percent of affected leaves by rust in parents was 57.99. The higher percent of affected leaves was recorded by the parent Narayani (85.33) and the lower percent of leaves affected was observed in GPBD-4 (14.97). In addition to Narayani, Kadiri-6 (82.27) and

Tirupati-1 (78.03) also recorded higher percent of rust affected leaves. The mean percent of rust affected leaves in F_2 population was 67.67. The highest percent of affected leaves was recorded in the cross Tirupati-1 x GPBD-4 (77.66) and lowest percent of affected leaves was observed in TCGS-876 x GPBD-4 (55.08). Percent of leaves affected by rust in F_2 populations was in between resistant and susceptible parents and more towards susceptible parent.

4.2.9 Latent Period in Days: The latent period *i.e.* time taken for the first appearance of symptom of LLS after artificial inoculation was highest in GPBD-4 (5.53 days) and lowest in Narayani (1.20 days). The mean latent period in parents was 2.04 days. In F_2 populations, it ranged from 1.33 days (Kadiri-6 x GPBD-4) to 1.97 days (TLG-45 x GPBD-4). The mean of the F_2 populations were 1.58 days.

4.2.10 LLS Score at 90 Days: Late leafspot incidence was high in Narayani (8.17) and the lowest incidence was observed in GPBD-4 (5.37). The mean value was 7.05. In the F_2 populations, the mean was 7.39 and the values ranged from 7.00 (TCGS-876 x GPBD-4) to 7.78 (Narayani x GPBD-4).

4.2.11 Rust Score at Harvest: The mean rust score of parents was 2.17. The highest rust incidence was observed in Kadiri-6 (2.77) and it was lowest in TLG-45 (1.70). F_2 populations showed a still higher mean rust score of 2.63, the highest value being 4.42 in Narayani x GPBD-4 and lowest being 1.97 in Abhaya x GPBD-4.

LLS and rust incidence in F_2 populations was lower than susceptible parents but higher than resistant parent, GPBD-4. In the season, the severity of LLS was very high and under such disease pressure, even resistant variety recorded a mean score of 5.37. Rust incidence was not that severe and even the highly susceptible varieties, Kadiri-6 (2.77) and Narayani (2.63) recorded lower scores while the resistant parent, GPBD-4 recorded a mean score of 1.90 and TCGS-876 recorded a still lower score of 1.70. The corresponding severity percent were also low for rust as well as for LLS. Most of the traits related to LLS and rust incidence seem to be mostly influenced by additive genetic variance as have been observed in the present study *i.e.* for these parameters F_2 means have surpassed means of better parents.

4.2.12 Pod Weight per Plant: The mean pod weight per plant of parents was 6.35g. It was highest in TCGS-876 (7.86g) among parents and it was low in GPBD-4 (4.91g). In the F_2 populations, the mean was 5.70g. It was high in TLG-45 x GPBD-4 (7.06g) and low in Kadiri-6 x GPBD-4 (4.62g).

In F_2 populations, pod weight per plant was lower than the parent with higher pod weight. For pod yield and its attributes, the mean of the F_2 populations was lower than the better parents which might be due to some undesirable combinations of alleles from resistant and susceptible parents. As the objective is incorporation of resistance into high yielding background, stress should be on selection of segregants with yield potential as in high yielding susceptible genotypes with moderate to high level of resistance in later generations.

4.3 VARIABILITY, HERITABILITY AND GENETIC ADVANCE IN F_2 GENERATION OF SIX CROSSES

Genotypic coefficient of variation gives the magnitude of genetic variability. Heritability gives the picture of heritable portion of phenotypic variance. Estimates of heritability together with variability and genetic advance help the plant breeder in planning breeding strategies for selection of suitable crosses for further advancement to advanced generations. It also helps the breeder in taking wise decisions like whether selection should be in early generations or it has to be postponed to later generations for a particular trait of interest depending on the mode of gene action.

Genetic parameters estimated in six crosses for different traits are discussed hereunder. PCV estimates were found to be higher than GCV

Table 4.2. Genetic parameters for 12 characters in six F_2 populations of groundnut (*Arachis hypogaea* L.)

Character	Mean	Range	Phenotypic variance	Genetic variance	Phenotypic coefficient of variation	Genotypic coefficient of variation	Heritability %	Genetic advance	Genetic advance as % of mean
Plant height (cm)									
Tirupati 1 x GPBD 4	43.43	31-66	44.7	8.92	15.39	6.88	19.96	2.75	6.33
Narayani x GPBD 4	53.59	35-73	70.9	20.34	15.71	8.42	28.69	4.98	9.29
Abhaya x GPBD 4	38.50	22-58	39.94	3.83	16.42	5.09	9.59	1.25	3.24
Kadiri 6 x GPBD 4	41.66	30-60	33.06	0	13.80	0.00	0.00	0.00	0.00
TLG 45 x GPBD 4	35.24	17-58	61.02	37.90	22.17	17.47	62.11	9.99	28.36
TCGS 876 x GPBD 4	47.92	31-61	42.88	8.20	13.67	5.98	19.12	2.58	5.38
Primary branches per plant									
Tirupati 1 x GPBD 4	4.39	2-6	0.47	0.22	15.62	10.56	46.81	0.66	15.06
Narayani x GPBD 4	4.33	3-6	0.27	0.04	12.00	4.32	14.81	0.16	3.66
Abhaya x GPBD 4	4.20	4-6	0.18	0.00	10.10	0.00	0.00	0.00	0.00
Kadiri 6 x GPBD 4	4.26	2-6	0.35	0.10	13.89	7.42	28.57	0.35	8.17
TLG 45 x GPBD 4	4.44	3-6	0.36	0.19	13.51	9.82	52.78	0.65	14.69
TCGS 876 x GPBD 4	4.56	2-6	0.5	0.19	15.51	9.43	38.00	0.55	12.14
Mature pods per plant									
Tirupati 1 x GPBD 4	9.70	2-20	17.18	0.94	42.73	10.00	5.47	0.47	4.82
Narayani x GPBD 4	8.86	1-22	15.52	3.22	44.46	20.24	20.75	1.68	19.00
Abhaya x GPBD 4	10.80	0-23	19.13	3.43	40.50	17.15	17.93	1.62	14.96
Kadiri 6 x GPBD 4	7.69	1-19	13.97	0	48.60	0.00	0.00	0.00	0.00
TLG 45 x GPBD 4	11.26	0-35	42.35	27.79	57.79	46.81	65.62	8.80	78.13
TCGS 876 x GPBD 4	9.82	2-33	25.29	8.24	51.21	29.22	32.58	3.38	34.37

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Character	Mean	Range	Phenotypic variance	Genetic variance	Phenotypic coefficient of variation	Genotypic coefficient of variation	Heritability %	Genetic advance	Genetic advance as % of mean
Immature pods per plant									
Tirupati 1 x GPBD 4	3.24	0-10	5.31	0	71.12	0.00	0.00	0.00	0.00
Narayani x GPBD 4	3.76	0-13	8.05	2.23	75.46	39.72	27.70	1.62	43.06
Abhaya x GPBD 4	4.72	0-16	9.06	3.83	63.77	41.44	42.27	2.62	55.53
Kadiri 6 x GPBD 4	3.29	0-8	2.16	0	44.67	0.00	0.00	0.00	0.00
TLG 45 x GPBD 4	6.99	1-19	12.19	5.38	49.95	33.17	44.13	3.17	45.41
TCGS 876 x GPBD 4	4.18	1-12	5.27	0.27	54.92	12.43	5.12	0.24	5.80
Shelling out turn (%)									
Tirupati 1 x GPBD 4	63.32	42-80	27.52	0	9.93	0.00	0.00	0.00	0.00
Narayani x GPBD 4	59.54	16-76	47.27	0	13.58	0.00	0.00	0.00	0.00
Abhaya x GPBD 4	56.01	0-79	86.54	12.58	19.24	7.34	14.54	2.79	5.76
Kadiri 6 x GPBD 4	65.89	33-78	39.92	0	11.60	0.00	0.00	0.00	0.00
TLG 45 x GPBD 4	57.73	26-78	43.47	0	13.31	0.00	0.00	0.00	0.00
TCGS 876 x GPBD 4	60.17	33-79	31.84	0	11.07	0.00	0.00	0.00	0.00
Harvest index (%)									
Tirupati 1 x GPBD 4	27.16	12-55	40.84	0	23.53	0.00	0.00	0.00	0.00
Narayani x GPBD 4	25.26	2-61	56.81	8.25	29.84	11.37	14.52	2.25	8.93
Abhaya x GPBD 4	27.71	0-44	60.85	0	28.15	0.00	0.00	0.00	0.00
Kadiri 6 x GPBD 4	30.16	6-54	55.03	2.87	24.60	5.61	5.22	0.80	2.64
TLG 45 x GPBD 4	37.73	9-69	49.31	0	18.61	0.00	0.00	0.00	0.00
TCGS 876 x GPBD 4	31.76	5-81	82.76	34.40	28.64	18.47	41.57	7.79	24.53

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Character	Mean	Range	Phenotypic variance	Genetic variance	Phenotypic coefficient of variation	Genotypic coefficient of variation	Heritability %	Genetic advance	Genetic advance as % of mean
Percentage of leaves affected by LLS									
Tirupati 1 x GPBD 4	92.19	62-100	42.57	21.75	8.70	6.22	51.09	6.87	9.16
Narayani x GPBD 4	90.43	70-100	63.12	32.40	10.80	7.74	51.33	8.40	11.42
Abhaya x GPBD 4	89.47	76-99	27.29	0	7.29	0.00	0.00	0.00	0.00
Kadiri 6 x GPBD 4	95.98	85-100	29.3	6.84	6.79	3.28	23.34	2.60	3.27
TLG 45 x GPBD 4	79.92	66-99	33.59	0	9.07	0.00	0.00	0.00	0.00
TCGS 876 x GPBD 4	80.18	74-99	13.04	0	5.66	0.00	0.00	0.00	0.00
Percentage of leaves affected by rust									
Tirupati 1 x GPBD 4	77.66	0-100	213.67	186.12	23.14	21.60	87.11	26.23	41.52
Narayani x GPBD 4	74.16	0-94	99.52	59.89	16.66	12.92	60.18	12.37	20.65
Abhaya x GPBD 4	62.41	0-91	108.73	93.75	19.95	18.53	86.22	18.52	35.44
Kadiri 6 x GPBD 4	75.50	43-98	90.46	75.26	15.52	14.16	83.20	16.30	26.60
TLG 45 x GPBD 4	61.20	51-85	23.97	15.06	9.49	7.52	62.83	6.34	12.28
TCGS 876 x GPBD 4	55.08	51-59	2.05	0	2.99	0.00	0.00	0.00	0.00
Latent period									
Tirupati 1 x GPBD 4	1.47	1-3	0.25	0	34.01	0.00	0.00	0.00	0.00
Narayani x GPBD 4	1.36	1-2	0.32	0	41.59	0.00	0.00	0.00	0.00
Abhaya x GPBD 4	1.71	1-5	0.59	0	44.92	0.00	0.00	0.00	0.00
Kadiri 6 x GPBD 4	1.33	1-3	0.36	0	45.11	0.00	0.00	0.00	0.00
TLG 45 x GPBD 4	1.97	1-7	1.2	0.36	55.61	30.24	30.00	0.68	34.36
TCGS 876 x GPBD 4	1.64	1-7	0.82	0	55.22	0.00	0.00	0.00	0.00

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Character	Mean	Range	Phenotypic variance	Genetic variance	Phenotypic coefficient of variation	Genotypic coefficient of variation	Heritability %	Genetic advance	Genetic advance as % of mean
Late leaf spot score at 90 DAS (1-9 scale)									
Tirupati 1 x GPBD 4	7.46	6-9	156.15	44.77	24.18	12.95	28.67	7.38	14.28
Narayani x GPBD 4	7.78	6-9	149.8	57.35	22.18	13.73	38.28	9.65	17.50
Abhaya x GPBD 4	7.28	5-9	167.6	45.07	26.01	13.49	26.89	7.17	14.41
Kadiri 6 x GPBD 4	7.57	5-9	119.82	6.19	20.70	4.70	5.17	1.16	2.20
TLG 45 x GPBD 4	7.27	4-9	116.82	13.20	21.97	7.39	11.30	2.52	5.11
TCGS 876 x GPBD 4	7.00	6-8	64.43	0	17.48	0.00	0.00	0.00	0.00
Rust score at 90 DAS (1-9 scale)									
Tirupati 1 x GPBD 4	2.47	1-5	79.24	13.72	73.20	30.46	17.31	3.18	26.11
Narayani x GPBD 4	4.42	2-9	357.14	311.64	67.88	63.41	87.26	33.97	122.02
Abhaya x GPBD 4	1.97	1-4	41.6	0	74.14	0.00	0.00	0.00	0.00
Kadiri 6 x GPBD 4	2.53	1-5	30.42	0	41.69	0.00	0.00	0.00	0.00
TLG 45 x GPBD 4	2.13	1-5	53.14	0	73.63	0.00	0.00	0.00	0.00
TCGS 876 x GPBD 4	2.28	1-5	58.78	0	69.95	0.00	0.00	0.00	0.00
Pod weight (g)									
Tirupati 1 x GPBD 4	4.86	0.64-10.17	5.65	0.00	48.91	0.00	0.00	0.00	0.00
Narayani x GPBD 4	5.12	0.15-11.16	6.23	4.53	48.75	41.57	72.71	3.74	73.02
Abhaya x GPBD 4	6.06	0.96-18.49	14.62	9.64	63.10	51.23	65.94	5.19	85.70
Kadiri 6 x GPBD 4	4.62	0.52-10.99	5.41	0.00	50.35	0.00	0.00	0.00	0.00
TLG 45 x GPBD 4	7.06	0.96-18.49	14.62	10.70	54.16	46.32	73.19	5.76	81.65
TCGS 876 x GPBD 4	6.47	0.97-24.24	15.03	8.02	59.92	43.77	53.36	4.26	65.87

estimates for all the traits in all the crosses indicating the influence of environment on expression of each trait. (Table 4.2)

4.3.1 Plant Height (cm): PCV estimates ranged from 13.67 (TCGS-876 x GPBD-4) to 22.17 (TLG-45 x GPBD-4). The highest PCV was observed in the F_2 population of TLG-45 x GPBD-4 (22.17) followed by Abhaya x GPBD-4 (16.42) and Narayani x GPBD-4 (15.71). GCV estimates ranged from 0.00 (Kadiri-6 x GPBD-4) to 17.47 (TLG-45 x GPBD-4).

Heritability ranged from 0 to 62.11. It was lower in Kadiri-6 x GPBD-4 (0) and higher in TLG-45 x GPBD-4 (62.11) followed by Narayani x GPBD-4 (28.69). Genetic advance as percent of mean was highest in F_2 population of TLG-45 x GPBD-4 (28.36) while it was lower in Kadiri-6 x GPBD-4 (0). GAM in other crosses was low.

The mean plant height ranged between 35.24 (TLG-45 x GPBD-4) and 53.59 (Narayani x GPBD-4). Plant height showed low heritability in all the crosses except TLG-45 x GPBD-4 where it was high. The GCV and PCV were also found to be low in all crosses. In TLG-45 x GPBD-4 alone, there was a moderate PCV. The GAM values were also found to be low in all crosses except in TLG-45 x GPBD-4. High genetic advance for a character in a population indicates that it is controlled by additive gene action. Hence phenotypic selection will be effective for improvement of plant height in this cross. The results are in agreement with the earlier results reported by Singh and Singh (1999) and Vijaya Sekhar (2002) who reported lower estimates of variability and GAM. The low GCV, heritability as well as GAM in five crosses might be due to less divergence among the parents involved for plant height. The studies of Uddin *et al*. (1995) and Azad and Hamid (2000) reported high GCV coupled with high genetic advance for plant height as obtained in the present study in the cross, TLG-45 x GPBD-4.

4.3.2 Primary Branches per Plant: The range of PCV was from 10.10 to 15.62. Maximum PCV was observed in F_2 population of Tirupati-1 x GPBD-4

(15.62) followed by TCGS-876 x GPBD-4 (15.51). The lowest PCV was observed in Abhaya x GPBD-4 (10.10). GCV ranged from zero (Abhaya x GPBD-4) to 10.56 (Tirupati-1 x GPBD-4)

Heritability estimates ranged from 0 to 52.78. Highest heritability was observed in TLG-45 x GPBD-4 (52.78) followed by Tirupati-1 x GPBD-4 (46.81). Lowest heritability was observed in Abhaya x GPBD-4 (0). Genetic advance as percent of mean ranged from 0 (Abhaya x GPBD-4) to 15.06 (Tirupati-1 x GPBD-4). Highest GAM was recorded by Tirupati-1 x GPBD-4 (15.06) followed by TLG-45 x GPBD-4 (14.69) and TCGS-876 (12.14). Negative estimates obtained in some of the crosses are represented as zero as per Allard (1960) as estimates of genetic parameters cannot be negative. Similar negative estimates were earlier reported in study of F_2 populations of five crosses of groundnut by Vasanthi and Raja Reddy (2002). This was attributed to high environmental variances in comparison with F_2 phenotypic variance. Variability for a particular trait may be lacking in segregating population of a particular cross due to similar genetic system operating in both the parents involved in that cross.

Number of primary branches is an important attribute in view of its role in deciding the final yield through number of pods per plant. Mean number of primary branches ranged from 4.20 (Abhaya x GPBD-4) to 4.56 (TCGS-876 x GPBD-4). The PCV and GCV values were found to be low in three crosses which might be due to the greater role of environment in the expression of the trait. The GCV, heritability and GAM were moderate in the crosses Tirupati-1 x GPBD-4, TLG-45 x GPBD-4 and TCGS-876 x GPBD-4, where in gene action could be additive and selection would be effective in early generations. In the other crosses, heritability as well as GAM was low as reported earlier by Quadri and Khunti (1982) and Vaddoria and Patel (1990).

4.3.3 Mature Pods per Plant: PCV varied among crosses and it ranged from 40.50 to 57.79. The highest value was observed in TLG-45 x GPBD-4 (57.79) which was followed by TCGS-876 x GPBD-4 (51.21) and Kadiri-6 x GPBD-4

(48.60). The lowest value among the crosses was observed in case of Abhaya x GPBD-4 (40.50). GCV ranged from 0 to 46.81. The highest value was observed in TLG-45 x GPBD-4 (46.81).

Heritability estimates ranged from 0 (Kadiri-6 x GPBD-4) to 65.62 (TLG-45 x GPBD-4). The highest value was observed in TLG-45 x GPBD-4 (65.62) followed by TCGS-876 x GPBD-4 (32.58).

GAM values among the crosses ranged from 0 (Kadiri-6 x GPBD-4) to 78.13 (TLG-45 x GPBD-4). The highest GAM was recorded in TLG-45 x GPBD-4 (78.13) followed by TCGS-876 x GPBD-4 (34.37).

Average number of mature pods per plant was high in TLG-45 x GPBD-4. Moderate PCV was observed in all the crosses. GCV was found to be moderate in the crosses, TLG-45 x GPBD-4 and TCGS-876 x GPBD-4. GCV along with heritability estimates provide a reliable estimate of the amount of genetic advance expected through phenotypic selection (Burton, 1952). High GAM value and moderate heritability was observed in the cross TCGS-876 x GPBD-4 which is in accordance with the earlier report of Nagabhushanam *et al.*(1982). Ganeshan and Sudhakaran (1995), Savaliya *et al.* (2009) and Raut *et al.* (2010) reported high heritability and genetic advance for number of mature pods which corroborates with the results obtained in the present study in the cross TLG-45 x GPBD-4 in which heritability and GAM were high .The mean mature pods per plant in the crosses TLG-45 x GPBD-4 (11.26) and TCGS-876 x GPBD-4 (9.82) were found to be fairly high along with moderate PCV, GCV, heritability and GAM values indicating that direct selection would be effective for improving number of mature pods per plant in these cross.

4.3.4 Immature Pods per Plant: PCV values ranged from 44.67 to 75.46. The highest value among the crosses was observed in Narayani x GPBD-4 (75.46) followed by Tirupati-1 x GPBD-4 (71.12) and Abhaya x GPBD-4 (63.77). The lowest value was observed in Kadiri-6 x GPBD-4 (44.67). GCV values ranged from 0 to 41.44. The highest GCV was observed in Abhaya x GPBD-4 (41.44) followed Narayani x GPBD-4 (39.72) and TLG-45 x GPBD-4 (33.17). The lowest GCV was observed in Tirupati-1 x GPBD-4 (0) and Kadiri-6 x GPBD-4 (0).

Heritability estimates varied among the crosses from 0 to 44.13. The highest value was observed inTLG-45 x GPBD-4 (44.13) closely followed by Abhaya x GPBD-4 (42.27). GAM ranged from 0 to 55.53 in the crosses. The highest value was recorded in Abhaya x GPBD-4 (55.53) followed TLG-45 x GPBD-4 (45.41) and Narayani x GPBD-4 (43.06).

The range of mean immature pods per plant was 3.24 (Tirupati-1 x GPBD-4) to 6.99 (TLG-45 x GPBD-4). The crosses *viz*., Narayani x GPBD-4, Abhaya x GPBD-4 and TLG-45 x GPBD-4 showed moderate to high PCV, moderate GCV, moderate heritability and moderate to high GAM. Phenotypic selection would be useful in making selections with lower number of immature pods per plant. Low to moderate heritability values were observed by Rami Reddy (1991).

4.3.5 Shelling Out-turn (percent): Shelling out-turn is an important quality trait that decides the economic value of the produce. PCV values ranged from 9.93 (Tirupati-1 x GPBD-4) to 19.24 (Abhaya x GPBD-4). The GCV was positive only in Abhaya x GPBD-4 (7.34). Heritability was found to be low in general and the highest value recorded was 14.54 in Abhaya x GPBD-4. GAM was also low in all the crosses and the highest value was 5.76 in Abhaya x GPBD-4. As the heritability was found to be low, it can be inferred that the expression is more influenced by environment.

The mean shelling percent was high in Kadiri-6 x GPBD-4 (65.89) and low in Abhaya x GPBD-4 (56.01). In all the crosses the PCV, GCV, heritability and genetic advance were found to be low. This may be due to the adverse effect of the environment which was very conducive for the incidence of LLS with a very high severity and the expression of trait was poor. Earlier, Khangura and Sandhu (1973) and Kandaswamy *et al.* (1986) reported low GCV for shelling out-turn.

4.3.6 Harvest Index (percent): PCV estimates ranged from 18.61 (TLG-45 x GPBD-4) to 29.84 (Narayani x GPBD-4). GCV ranged from 0 to 18.47 (TCGS-876 x GPBD-4). The highest value was registered in TCGS-876 x GPBD-4 (18.47). GCV values were moderate in two crosses, Narayani x GPBD-4 and TCGS-876 x GPBD-4.

Heritability estimates ranged between zero (Tirupati x GPBD-4, Abhaya x GPBD-4 and TLG-45 x GPBD-4) and 41.57 (TCGS-876 x GPBD-4). The values of genetic advance as percent of mean ranged from zero (Tirupati x GPBD-4, Abhaya x GPBD-4 and TLG-45 x GPBD-4) to 24.53 (TCGS-876 x GPBD-4).

Harvest index is a reliable indicator of the economic yield out of the total biomass *i.e.*, partitioning efficiency. In the present study, the mean harvest index ranged from 25.26 percent (Narayani x GPBD-4) to 37.73 percent (TLG-45 x GPBD-4). Heritability was found to be low in all the crosses except in TCGS-876 x GPBD-4 in which it was moderate. GAM was also low in all the crosses except in TCGS-876 x GPBD-4. The results are in agreement with earlier reports of Harisingh *et al.* (1982) and Varman and Raveendran (1996) who reported low heritability and low GAM.

During *kharif*, 2010, as disease pressure was very high, pod as well as haulms yield suffered in susceptible genotypes. Hence, in crosses involving one susceptible and one resistant parent, the F_2 population mean was towards susceptibility and population did not show much variability with respect to pod and haulms yield that decide ultimately the harvest index. In the cross, TCGS-876 x GPBD-4, TCGS-876 was moderately susceptible and GPBD-4 was resistant to LLS and hence in this cross only GAM was high. Even GPBD-4, the resistant parent recorded moderate level of incidence of LLS and rust. Vijayasekhar (2002) reported high GCV, heritability and GAM for harvest index.

4.3.7 Percent of Leaves Affected by LLS: PCV values were highest in Narayani x GPBD-4 (10.80) and lowest in TCGS-876 x GPBD-4 (5.66). GCV estimates ranged from zero (Abhaya x GPBD-4, TLG-45 x GPBD-45 and TCGS-876 x GPBD-4) to 7.74 (Narayani x GPBD-4). Heritability estimates ranged from zero (Abhaya x GPBD-4, TLG-45 x GPBD-45 and TCGS-876 x GPBD-4) to 51.33 (Narayani x GPBD-4). The highest value was observed in Narayani x GPBD-4 (51.33) followed by Tirupati 1 x GPBD-4 (51.09). The values of GAM ranged from 0 (Abhaya x GPBD-4, TLG-45 x GPBD-45 and TCGS-876 x GPBD-4) to 11.42 (Narayani x GPBD-4).

Low PCV and GCV values were recorded for percent of leaves affected by LLS. Heritability was low in all the crosses except Tirupati-1 x GPBD-4 and Narayani x GPBD-4 where it was moderate. GAM was observed to be low in all the crosses except Narayani x GPBD-4 where it was moderate. Gowda *et al.* (1996) reported a high variability coupled with high genetic advance for number of LLS affected leaves indicating the involvement of additive gene action. In two crosses, Narayani x GPBD-4 and Tirupati-1 x GPBD-4, involving highly susceptible and highly resistant parents, the variability expressed was relatively high in comparison with other cross combinations and hence moderate genetic advance coupled with moderate heritability estimates were obtained in the present study in these two crosses.

4.3.8 Percent of Leaves Affected by Rust: The values of PCV were highest in F_2 population of Tirupati-1 x GPBD-4 (23.14) and lowest in TCGS-876 x GPBD-4 (2.99). The highest PCV was in Tirupati-1 x GPBD-4 (23.14) followed by Abhaya x GPBD-4 (19.95). The values of GCV ranged from zero (TCGS-876 x GPBD-4) to 21.60 (Tirupati-1 x GPBD-4). The highest value was recorded in Tirupati-1 x GPBD-4 (21.60) followed by Abhaya x GPBD-4 (18.53) and Kadiri-6 x GPBD-4 (14.16).

The estimates of heritability were found to range from zero (TCGS-876 x GPBD-4) to 87.11 (Tirupati-1 x GPBD-4). The highest value was observed in Tirupati 1 x GPBD-4 (87.11) followed by Abhaya x GPBD-4 (86.22) and Kadiri-6 x GPBD-4 (83.20). GAM values ranged from zero (TCGS-876 x GPBD-4) to 41.52 (Tirupati-1 x GPBD-4). The highest GAM was registered in

Tirupati-1 x GPBD-4 (41.52) followed by Abhaya x GPBD-4 (35.44) and Kadiri-6 x GPBD-4 (26.60).

The estimates of PCV and GCV were found to be low in five crosses Abhaya x GPBD-4, Narayani x GPBD-4, Kadiri-6 x GPBD-4, TLG-45 x GPBD-4 and TGS-876 x GPBD-4 while it was moderate to high in Tirupati-1 x GPBD-4. The heritability was found to be high in all the crosses except in TCGS-876 x GPBD-4. GAM was found to be high in all the crosses except in TLG-45 x GPBD-4 in which it was moderate. These results indicate that the character is controlled by both additive and non additive gene action. Phenotypic selection in early generations would be rewarding in these five crosses. To capture non-additive variance, it is necessary to postpone the selection to later generations where in the confusing effects of dominance and epistasis get dissipated or to attempt biparental matings in F_3 or F_4 generations.

4.3.9 Latent Period (Days): PCV estimates ranged from 34.01 to 55.61. The highest value was observed in TLG-45 x GPBD-4 (55.61) followed by TCGS-876 x GPBD-4 (55.22) and Kadiri-6 x GPBD-4 (45.11). A non-zero value for latent period was observed only in TLG-45 x GPBD-4 (30.24). Similar was the case with heritability and GAM values. Only in TLG-45 x GPBD-4, heritability was 30 percent and GAM was 34.36 percent.

The mean value for latent period varied from 1.33 (Kadiri-6 x GPBD-4) to 1.97 (TLG-45 x GPBD-4). The PCV values ranged from moderate to high while the GCV values were found to be low in all crosses except in TLG-45 x GPBD-4 in which it was moderate. GAM was found to be low in all crosses except TLG-45 x GPBD-4.

4.3.10 LLS Score at 90 DAS (1-9 scale) (in terms of disease severity in percent): The PCV values ranged from 17.48 to 26.01. The highest value was observed in Abhaya x GPBD-4 (26.01) followed by Tirupati-1 x GPBD-4 (24.18) and Narayani x GPBD-4 (22.18). The values of GCV ranged from zero to 13.73. The highest GCV was recorded in Narayani x GPBD-4 (13.73) followed by Abhaya x GPBD-4 (13.49) and Tirupati-1 x GPBD-4 (12.95).

Heritability ranged from zero to 38.28. The highest value was observed in Narayani x GPBD-4 (38.28) followed by Tirupati-1 x GPBD-4 (28.67) and Abhaya x GPBD-4 (26.89). The lowest value, zero was observed in TCGS-876 x GPBD-4. The GAM values ranged from zero to 17.50. The highest value was recorded by Narayani x GPBD-4 (17.50) followed by Abhaya x GPBD-4 (14.41) and Tirupati-1 x GPBD-4 (14.28). The lowest value was observed in TCGS-876 x GPBD-4.

The mean values ranged from 51.5 (TCGS-876 x GPBD-4) and 65.72 (Narayani x GPBD-4).The PCV values were moderate in all the crosses except in TCGS-876 x GPBD-4 in which it was low. The estimates of GCV were low in all the crosses. Heritability and GAM estimates were moderate in three crosses, Narayani x GPBD-4, Tirupati-1 x GPBD-4 and Abhaya x GPBD-4. In the aforesaid three crosses, the gene action appears to be of both additive and non-additive type and selection would be effective in early generations in recovering resistant lines. To capture variability that is due to non-additive gene action biparental mating between F_3 and F_4 segregants would be useful.

In studies of Khedikar *et* al. (2010), PCV estimates were found to be high (from 21.71 to 33.55percent) at different stages and environments for LLS. Heritability ranged from 40.87 to 82.81percent in TAG-24 x GPBD-4. TAG-24 recorded a mean disease score of 4.75 - 9.00 for LLS and 3.71 – 8.00 for rust while GPBD-4 recorded consistently lower disease incidence than TAG-24 (LLS: 1.00 – 3.50 and rust: 3.71 – 8.00). Phenotypic data on 268 RILs showed near-normal distribution for both the diseases, but slightly towards susceptibility at later stages (at 90 DAS).

4.3.11 Rust Score at Harvest (1-9 scale): The highest PCV was recorded in Abhaya x GPBD-4 (74.14) followed by TLG-45 x GPBD-4 (73.63) and Tirupati-1 x GPBD-4 (73.20). The lowest value recorded was 41.69 (Kadiri-6 x GPBD-4). The values of GCV ranged from zero to 63.41. The highest GCV was observed in Narayani x GPBD-4 (63.41) followed by Tirupati-1 x GPBD-4 (30.46) and in all the other crosses, values were zero.

The heritability was 87.26 in Narayani x GPBD-4 followed by 17.31 in Tirupati-1 x GPBD-4. In the same manner, GAM values were found to be 122.02 (Narayani x GPBD-4) followed by 26.11 (Tirupati-1 x GPBD-4).

Phenotypic selection would be useful in selection of plants with lower rust score in these two crosses. Khedikar *et al.* (2010) reported moderate to high PCV (15.83 – 59.58%) and high to very high heritability (34 – 89 %) in different screening environments.

4.3.12 Pod Weight per Plant (g): PCV values ranged from 48.91 to 63.10. The highest value was observed in Abhaya x GPBD-4 (63.10) followed by TCGS-876 x GPBD-4 (59.92) and TLG-45 x GPBD-4 (54.16). The lowest PCV was recorded in Narayani x GPBD-4 (48.75). The values of GCV ranged from zero to 51.23. The highest value was recorded by Abhaya x GPBD-4 (51.23) followed by TLG-45 x GPBD-4 (46.23) and TCGS-876 x GPBD-4 (43.77). The lowest value observed was zero, in two crosses, Tirupati-1 x GPBD-4 and Kadiri-6 x GPBD-4.

The heritability estimates ranged from zero to 73.19. The highest value was observed in TLG-45 x GPBD-4 (73.19) followed by Narayani x GPBD-4 (72.71). The lowest value, zero was observed in Tirupati-1 x GPBD-4 and Kadiri-6 x GPBD-4. The GAM values ranged from zero to 85.70. The highest value was recorded by Abhaya x GPBD-4 (85.70) followed by TLG-45 x GPBD-4 (81.65), Narayani x GPBD-4 (73.02) and TCGS-876 x GPBD-4 (65.81). The lowest value, zero was observed in Tirupati-1 x GPBD-4 and Kadiri-6 x GPBD-4.

Earlier Kandaswamy *et al.* (1986), Ahamed (1995), Ganeshan and Sudhakar (1995) and Singh and Singh (1999) reported moderate values of variability coupled with high genetic advance for pod yield which are in agreement with the results in the present study. Pod yield seems to be more influenced by additive gene action in these crosses which recorded high GCV, heritability and genetic advance in F_2 generation and hence, selection would be effective in early segregating generations.

4.4 CHARACTER ASSOCIATION

Analysis of correlation is of interest to know the causal relationship between two characters. If primary character *i.e.* pod yield has a low heritability, consideration of several characters with high heritability correlated to primary character *i.e.* indirect selection increases the efficiency of selection for yield. The secondary characters that are easier to measure than the primary character can be identified through correlation studies. Such secondary characters can be used for preliminary screening with low selection intensity and mainly in the early generations of selection. Correlation between two characters may result from linkage and / or pleiotropy. If caused by linkage, an undesirable correlation can be changed through hybridization followed by selection in segregating generations. Correlations worked out between pod yield and other attributes in individual crosses and parents are discussed hereunder. In the present study, correlations were computed in individual crosses (intra-cross correlations) and in individual parents so that the comparison of correlations would be more logical.

4.4.1 Character Association in Parents

4.4.1.1 Tirupati-1: Pod yield showed significant positive association with mature pods per plant (0.7947), shelling out-turn (0.3924), harvest index (0.5217) and latent period (0.6684). It showed negative significant association with LLS severity (-0.632) and rust severity (0.5511) (Table 4.3).

With plant height, negative and significant association was found with number of immature pods per plant (-0.466), percent of leaves affected by LLS (-0.357) and rust severity (-0.4033). Number of primary branches showed negative and significant association with LLS severity (-0.3906).

Table 4.3 Correlation coefficients in F_2 population of Tirupati-1 x GPBD-4 in comparison with the parents for 12 characters

Characters		PH	PB	MP	IP	SO	HI	LLS%	Rust %	LP	LLS Score	Rust score
Pod weight	**P1**	0.2462	0.2731	0.7947**	-0.186	0.3924*	0.5217**	-0.216	-0.1464	0.6684**	-0.632**	-0.5511**
	F_2	0.0669	0.1694	0.8005**	0.076	0.3531**	0.7072**	-0.4235**	-0.4278**	0.5553**	-0.399**	-0.353**
	P7	0.4821**	0.1699	0.6325**	0.4765**	0.2498	0.8669**	-0.073	-0.1214	0.1382	-0.289	-0.0557
Plant height	**P1**		-0.164	0.2552	-0.466**	0.2599	0.0076	-0.357*	0.1406	0.175	-0.1459	-0.4033*
	F_2		0.0957	0.0275	-0.161	-0.011	-0.172	0.0732	0.1245	0.006	0.1159	0.1075
	P7		0.2335	0.541**	0.5027**	0.4287**	0.2488	-0.045	0.3267*	0.059	-0.201	-0.379*
Primary branches	**P1**			0.2423	0.2592	-0.048	-0.069	-0.074	-0.077	0.2979	-0.3906**	-0.0055
	F_2			0.2683**	0.0532	-0.007	-0.034	-0.1043	-0.18	0.2189*	0.0818	-0.002
	P7			0.2707	0.041	-0.095	-0.002	-0.028	-0.13	0.0083	-0.011	-0.2
Mature pods	**P1**				-0.255	0.4653**	0.6116**	-0.072	0.33*	0.7729**	-0.7009**	-0.4038*
	F_2				0.1383	0.0922	0.5138**	-0.3178**	-0.4423**	0.7327**	-0.358**	-0.348**
	P7				0.4027**	0.2865	0.3208*	-0.161	0.0269	0.185	-0.379*	-0.45
Immature pods	**P1**					-0.55**	-0.33*	0.1028	-0.21	-0.099	0.3082**	-0.0257
	F_2					-0.311**	-0.168	-0.2858**	-0.1997*	0.0849	-0.106	0.2264*
	P7					0.3518*	0.33*	-0.066	0.0705	0.0935	-0.252	-0.373*
Shelling out-turn	**P1**						0.6549**	-0.076	0.4777**	0.1672	-0.2864**	-0.2438
	F_2						0.4706**	-0.0841	-0.071	0.0556	-0.001	-0.056
	P7						0.12	-0.245	0.2127	0.2105	-0.433**	-0.22
Harvest index	**P1**							0.0202	0.4824**	0.409*	-0.2838**	-0.2412
	F_2							-0.2968**	-0.2681**	0.3747**	-0.294**	-0.327**
	P7							0.0567	0.1049	0.0182	-0.235	-0.462**
LLS affected leaves (%)	**P1**								0.5591**	-0.136	0.0970	0.2734
	F_2								0.2343*	-0.282**	0.2745**	-0.031
	P7								0.1796	-0.925**	0.0105	-0.01
Rust affected leaves (%)	**P1**									0.0547	-0.1373	-0.2316
	F_2									-0.316**	0.3079**	0.2306*
	P7									-0.208	-0.156	-0.24
LP	**P1**										-0.5128**	-0.3459*
	F_2										-0.325**	-0.321**
	P7										-0.05	0.0183
LLS score	**P1**											0.253
	F_2											0.0884
	P7											0.3307*

P1- Tirupati-1, P7-GPBD-4, *Significant at 5%, ** Significant at 1%

Table 4.4 Correlation coefficients in F_2 population of Narayani x GPBD-4 in comparison with the parents for 12 characters

Characters		PH	PB	MP	IP	SO	HI	LLS%	Rust %	LP	LLS Score	Rust score
Pod weight	**P2**	-0.289	0.0047	0.1446	0.0137	-0.035	0.8177**	-0.713**	-0.47**	0.5263**	-0.651**	-0.6232**
	F_2	0.0894	0.0188	0.7757**	0.0311	0.4415**	0.7501**	-0.5077**	-0.1833*	0.6204**	-0.5814**	-0.5954**
	P7	0.4821**	0.1699	0.6325**	0.4765**	0.2498	0.8669**	-0.073	-0.1214	0.1382	-0.289	-0.0557
Plant height	**P2**		-0.229	-0.544**	-0.532**	0.1982	-0.442**	0.4488**	0.3658*	-0.173	0.421*	0.4059**
	F_2		-0.043	0.195*	0.1622	-0.101	-0.167	0.08025	0.06041	0.1251	-0.0834	-0.1006
	P7		0.2335	0.541**	0.5027**	0.4287**	0.2488	-0.045	0.3267*	0.059	-0.201	-0.379*
Primary branches	**P2**			0.0802	0.3878*	0.3072*	-0.065	-0.211	0.044	0.2469	-0.045	0.0552
	F_2			0.0513	0.0635	-0.089	-0.123	-0.0866	-0.1741	-0.025	-0.1373	-0.1578
	P7			0.2707	0.041	-0.095	-0.002	-0.028	-0.13	0.0083	-0.011	-0.2
Mature pods	**P2**				0.2829	-0.195	0.241	-0.147	-0.025	0.1895	-0.386*	-0.3003
	F_2				0.0752	0.1482	0.4814**	-0.3067**	-0.1022	0.8028**	-0.4881**	-0.5379**
	P7				0.4027**	0.2865	0.3208*	-0.161	0.0269	0.185	-0.379*	-0.45
Immature pods	**P2**					-0.112	0.1734	-0.284	-0.053	0.1819	0.0581	-0.006
	F_2					-0.077	-0.112	0.2237*	0.1437	0.1244	-0.0068	-0.0402
	P7					0.3518*	0.33*	-0.066	0.0705	0.0935	-0.252	-0.373*
Shelling out-turn	**P2**						-0.055	0.1274	0.0067	0.0575	0.0048	0.0549
	F_2						0.5808**	-0.5143**	-0.1322	0.051	-0.3597**	-0.2274*
	P7						0.12	-0.245	0.2127	0.2105	-0.433**	-0.22
Harvest index	**P2**							-0.715**	-0.463**	0.2834	-0.594**	-0.5196**
	F_2							-0.6024**	-0.253**	0.3409**	-0.4851**	-0.4282**
	P7							0.0567	0.1049	0.0182	-0.235	-0.462**
LLS affected leaves (%)	**P2**								0.491**	-0.512**	0.5516**	0.5997**
	F_2								0.3458**	-0.183*	0.407**	0.291**
	P7								0.1796	-0.925**	0.0105	-0.01
Rust affected leaves (%)	**P2**									-0.435**	0.2153	0.3753*
	F_2									-0.072	0.1033	0.0791
	P7									-0.208	-0.156	-0.24
LP	**P2**										-0.277	-0.2801
	F_2										-0.3055**	-0.339**
	P7										-0.05	0.0183
LLS score	**P2**											0.6411**
	F_2											0.3567**
	P7											0.3307*

P2- Narayani, P7-GPBD-4, *Significant at 5%, ** Significant at 1%

Table 4.5 Correlation coefficients in F_2 population of Abhaya x GPBD-4 in comparison with the parents for 12 characters

Characters		PH	PB	MP	IP	SO	HI	LLS%	Rust %	LP	LLS Score	Rust score
Pod weight	**P3**	-0.3349*	0.0039	0.7584**	0.0944	0.2624	0.84**	-0.551**	-0.595**	0.6485**	-0.837**	-0.5591**
	F_2	0.0194	0.0509	0.0935	-0.0634	-0.033	-0.0041	-0.0829	-0.1248	0.102	-0.5255**	-0.5288**
	P7	0.4821**	0.1699	0.6325**	0.4765**	0.2498	0.8669**	-0.073	-0.1214	0.1382	-0.289	-0.0557
Plant height	**P3**		-0.021	-0.2587	-0.099	-0.1428	-0.471**	0.165	0.5074**	-0.31*	0.3407*	0.0033
	F_2		-0.0787	0.237*	0.0936	0.1645	0.0356	-0.1058	0.0807	0.0695	0.1471	0.1780
	P7		0.2335	0.541**	0.5027**	0.4287**	0.2488	-0.045	0.3267*	0.059	-0.201	-0.379*
Primary branches	**P3**			0.2264	0.3312*	0.1436	-0.011	-0.259	0.105	0.0548	0.0067	-0.0518
	F_2			-0.0922	0.1131	0.1825*	0.0471	-0.0116	-0.0282	-0.0273	-0.102	-0.0451
	P7			0.2707	0.041	-0.095	-0.002	-0.028	-0.13	0.0083	-0.011	-0.2
Mature pods	**P3**				0.2387	0.0621	0.6304**	-0.488**	-0.632**	0.8508**	-0.58**	-0.4485**
	F_2				0.2527**	0.2408*	0.4827**	-0.3117**	0.1211	0.8323**	0.0678	0.0202
	P7				0.4027**	0.2865	0.3208*	-0.161	0.0269	0.185	-0.379*	-0.45
Immature pods	**P3**					-0.1775	0.0329	-0.133	-0.053	0.2623	-0.021	-0.2391
	F_2					0.2743**	0.2675**	-0.3532**	0.1689	0.208*	0.0212	-0.1285
	P7					0.3518*	0.33*	-0.066	0.0705	0.0935	-0.252	-0.373*
Shelling out-turn	**P3**						0.3484*	0.0505	0.0999	-0.126	-0.188	-0.1224
	F_2						0.5698**	-0.1938*	0.1785*	0.0337	-0.0036	0.0276
	P7						0.12	-0.245	0.2127	0.2105	-0.433**	-0.22
Harvest index	**P3**							-0.299	-0.396*	0.4893**	-0.756**	-0.3547*
	F_2							-0.3253**	0.2977**	0.2538**	-0.0097	-0.0669
	P7							0.0567	0.1049	0.0182	-0.235	-0.462**
LLS affected leaves (%)	**P3**								0.5756**	-0.479**	0.4293**	0.4433**
	F_2								0.0404	-0.2152*	0.0660	0.0457
	P7								0.1796	-0.925**	0.0105	-0.01
Rust affected leaves (%)	**P3**									-0.598**	0.3787*	0.3118*
	F_2									0.1251	0.2379	0.1812
	P7									-0.208	-0.156	-0.24
LP	**P3**										-0.513**	-0.4703**
	F_2										-0.0172	-0.0416
	P7										-0.05	0.0183
LLS score	**P3**											0.5023**
	F_2											0.4758**
	P7											0.3307*

P3- Abhaya, P7-GPBD-4, *Significant at 5%, ** Significant at 1%

Table 4.6 Correlation coefficients in F_2 population of Kadiri-6 x GPBD-4 in comparison with the parents for 12 characters

Characters		PH	PB	MP	IP	SO	HI	LLS%	Rust %	LP	LLS Score	Rust score
Pod weight	**P4**	0.0356	0.1928	0.8025**	0.0292	0.1586	0.666**	-0.305	-0.259	0.679**	-0.3242*	-0.598**
	F_2	0.0563	0.0973	0.854**	-0.03	0.1696	0.763**	-0.215*	-0.1359	0.6555**	-0.2724**	-0.2114*
	P7	0.4821**	0.1699	0.6325**	0.4765**	0.2498	0.8669**	-0.073	-0.1214	0.1382	-0.289	-0.0557
Plant height	**P4**		0.2294	0.0738	0.1786	-0.048	-0.378*	-0.035	0.3249*	0.1373	-0.1553	0.1871
	F_2		-0.185*	0.0389	0.1275	-0.121	-0.0799	0.0235	0.3708**	0.0272	0.0569	0.03581
	P7		0.2335	0.541**	0.5027**	0.4287**	0.2488	-0.045	0.3267*	0.059	-0.201	-0.379*
Primary branches	**P4**			0.0626	0.4226**	0.1841	-0.13	0.097	-0.001	0.009	-0.0356	-0.129
	F_2			0.2194*	0.0563	-0.191*	-0.1626	0.1089	-0.2212*	0.1373	-0.0496	-0.0452
	P7			0.2707	0.041	-0.095	-0.002	-0.028	-0.13	0.0083	-0.011	-0.2
Mature pods	**P4**				-0.01	-0.123	0.4887**	-0.444**	-0.256	0.7768**	-0.3618*	-0.562**
	F_2				-0.008	-0.052	0.5025**	-0.226*	-0.068	0.8339**	-0.262**	-0.218*
	P7				0.4027**	0.2865	0.3208*	-0.161	0.0269	0.185	-0.379*	-0.45
Immature pods	**P4**					-0.066	-0.293	0.119	0.1006	0.0123	-0.0714	0.1229
	F_2					-0.221*	-0.291**	0.2196*	-0.0017	0.0042	0.0871	0.06501
	P7					0.3518*	0.33*	-0.066	0.0705	0.0935	-0.252	-0.373*
Shelling out-turn	**P4**						0.1525	0.324*	-0.045	0.0737	-0.0161	-0.23
	F_2						0.4439**	0.0215	0.2117*	-0.169	-0.2636**	-0.0258
	P7						0.12	-0.245	0.2127	0.2105	-0.433**	-0.22
Harvest index	**P4**							-0.297	-0.369*	0.3014	-0.1269	-0.502**
	F_2							-0.272**	0.3535**	0.2777**	-0.2819**	-0.2367*
	P7							0.0567	0.1049	0.0182	-0.235	-0.462**
LLS affected leaves (%)	**P4**								0.4267**	-0.312*	0.4679**	0.0984
	F_2								0.1226	-0.268**	0.0125	0.3119**
	P7								0.1796	-0.925**	0.0105	-0.01
Rust affected leaves (%)	**P4**									-0.059	0.2196	0.3295*
	F_2									-0.147	-0.0026	0.1531
	P7									-0.208	-0.156	-0.24
LP	**P4**										-0.4017*	-0.376*
	F_2										-0.0877	-0.0255
	P7										-0.05	0.0183
LLS score	**P4**											0.3467*
	F_2											0.1000
	P7											0.3307*

P4- Kadiri-6, P7-GPBD-4, *Significant at 5%, ** Significant at 1%

Table 4.7 Correlation coefficients in F_2 population of TLG-45 x GPBD-4 in comparison with the parents for 12 characters

Characters		PH	PB	MP	IP	SO	HI	LLS%	Rust %	LP	LLS Score	Rust score
Pod weight	**P5**	-0.0295	0.3921*	0.7683**	-0.022	0.0752	0.7508**	-0.0958	-0.196	0.4939**	-0.1609	-0.39*
	F_2	0.3476**	0.2958**	0.8216**	0.1063	0.0223	0.5907**	-0.3199**	-0.2463**	0.6927**	-0.137	-0.023
	P7	0.4821**	0.1699	0.6325**	0.4765**	0.2498	0.8669**	-0.073	-0.1214	0.1382	-0.289	-0.0557
Plant height	**P5**		0.4467**	-0.024	-0.074	0.1114	-0.176	-0.281	0.159	0.0431	-0.2106	-0.171
	F_2		-0.088	0.3**	-0.282**	-0.241*	0.0085	-0.0041	-0.0082	0.1571	0.1016	0.3084**
	P7		0.2335	0.541**	0.5027**	0.4287**	0.2488	-0.045	0.3267*	0.059	-0.201	-0.379*
Primary branches	**P5**			0.2283	-0.028	0.0753	0.1879	-0.019	-0.203	0.2568	-0.1713	-0.336*
	F_2			0.315**	0.104	0.0826	0.0921	-0.0327	0.0402	0.2953**	-0.013	0.0764
	P7			0.2707	0.041	-0.095	-0.002	-0.028	-0.13	0.0083	-0.011	-0.2
Mature pods	**P5**				0.12	-0.138	0.5341**	0.0884	-0.31	0.7033**	-0.1261	-0.313*
	F_2				0.104	-0.062	0.3824**	-0.2996**	-0.1957*	0.885**	-0.09	0.125
	P7				0.4027**	0.2865	0.3208*	-0.161	0.0269	0.185	-0.379*	-0.45
Immature pods	**P5**					-0.34*	-0.4*	-0.125	-0.172	0.0195	-0.1337	-0.233
	F_2					-0.054	-0.002	0.1118	0.1353	0.2583**	0.0839	-0.161
	P7					0.3518*	0.33*	-0.066	0.0705	0.0935	-0.252	-0.373*
Shelling out-turn	**P5**						0.4324**	0.1626	0.0248	-0.044	-0.1407	-0.019
	F_2						0.3904**	-0.1769*	-0.0528	-0.001	-0.214*	-0.104
	P7						0.12	-0.245	0.2127	0.2105	-0.433**	-0.22
Harvest index	**P5**							0.0985	-0.305	0.334*	-0.1084	-0.174
	F_2							-0.4966**	-0.4503**	0.2664**	-0.347**	-0.16
	P7							0.0567	0.1049	0.0182	-0.235	-0.462**
LLS affected leaves (%)	**P5**								-0.081	0.1611	-0.0637	-0.132
	F_2								0.6941**	-0.236*	0.6809**	0.1787*
	P7								0.1796	-0.925**	0.0105	-0.01
Rust affected leaves (%)	**P5**									-0.47**	0.058	0.1101
	F_2									-0.145	0.5072**	0.2247*
	P7									-0.208	-0.156	-0.24
LP	**P5**										-0.0775	0.0719
	F_2										-0.054	0.069
	P7										-0.05	0.0183
LLS score	**P5**											0.3847*
	F_2											0.3465**
	P7											0.3307*

P5- TLG-45, P7-GPBD-4, *Significant at 5%, ** Significant at 1%

Table 4.8 Correlation coefficients in F_2 population of TCGS-876 x GPBD-4 in comparison with the parents for 12 characters

Characters		PH	PB	MP	IP	SO	HI	LLS%	Rust %	LP	LLS Score	Rust score
Pod weight	**P6**	0.5288**	0.5381**	0.8458**	0.2177	0.2785	0.8197**	-0.1326	-0.3962*	0.7561**	-0.473**	-0.396*
	F_2	0.0486	0.2339*	0.8946**	-0.033	0.2276*	0.6383**	-0.1864*	-0.022	0.8692**	-0.1258	-0.1219
	P7	0.4821**	0.1699	0.6325**	0.4765**	0.2498	0.8669**	-0.073	-0.1214	0.1382	-0.289	-0.0557
Plant height	**P6**		0.4565**	0.5465**	0.2199	-0.085	0.2094	-0.1699	-0.3343*	0.54**	-0.139	-0.242
	F_2		0.0679	-0.003	-0.0716	-0.3	-0.392**	0.1933*	0.051	0.0124	0.1219	-0.2238*
	P7		0.2335	0.541**	0.5027**	0.4287**	0.2488	-0.045	0.3267*	0.059	-0.201	-0.379*
Primary branches	**P6**			0.5772**	0.116	0.0059	0.3051	-0.1021	-0.2902	0.5412**	-0.349*	-0.048
	F_2			0.2088*	0.1743	0.0466	-0.063	-0.0265	0.052	0.1372	-0.052	-0.0468
	P7			0.2707	0.041	-0.095	-0.002	-0.028	-0.13	0.0083	-0.011	-0.2
Mature pods	**P6**				0.1478	0.1703	0.6575**	-0.1461	-0.3321*	0.8548**	-0.352	-0.488**
	F_2				-0.0021	0.1164	0.5665**	-0.1674	-0.028	0.9332**	-0.0508	-0.0836
	P7				0.4027**	0.2865	0.3208*	-0.161	0.0269	0.185	-0.379*	-0.45
Immature pods	**P6**					-0.316*	0.0546	0.2104	0.0537	0.2626	0.1228	-0.041
	F_2					-0.277**	-0.179*	0.1693	-0.093	0.0037	-0.1335	-0.0014
	P7					0.3518*	0.33*	-0.066	0.0705	0.0935	-0.252	-0.373*
Shelling out-turn	**P6**						0.449**	-0.0432	0.0063	0.1104	-0.292	-0.142
	F_2						0.4591**	-0.2709**	0.019	0.1157	-0.0271	-0.057
	P7						0.12	-0.245	0.2127	0.2105	-0.433**	-0.22
Harvest index	**P6**							-0.0331	-0.273	0.5099**	-0.478**	-0.339*
	F_2							-0.2752**	0.004	0.4899**	-0.1089	0.067
	P7							0.0567	0.1049	0.0182	-0.235	-0.462**
LLS affected leaves (%)	**P6**								-0.2363	-0.1441	0.3383*	0.1758
	F_2								0.067	-0.083	0.0453	-0.0692
	P7								0.1796	-0.925**	0.0105	-0.01
Rust affected leaves (%)	**P6**									-0.3059*	0.048	0.0173
	F_2									-0.018	0.1273	-0.1088
	P7									-0.208	-0.156	-0.24
LP	**P6**										-0.276	-0.267
	F_2										-0.0607	-0.0987
	P7										-0.05	0.0183
LLS score	**P6**											0.1407
	F_2											0.0293
	P7											0.3307*

P6- TCGS-876, P7-GPBD-4, *Significant at 5%, ** Significant at 1%

Number of mature pods per plant showed a positive significant association with shelling out-turn (0.4653), harvest index (0.6116), percent of leaves affected by rust (0.33) and latent period (0.7729) and negative significant association with LLS severity (-0.7009) and rust severity (-0.4038). Number of immature pods per plant recorded positive significant association with LLS severity (0.3082) and negative significant association with shelling out-turn (-0.55) and harvest index (-0.33).

Shelling out-turn showed a positive significant association with harvest index (0.6549) and percent of leaves affected by rust (0.4777). Harvest index was positively and significantly associated with percent of leaves affected by rust (0.4824) and latent period (0.409).

4.4.1.2 Narayani: Narayani showed high susceptibility to both the foliar diseases. Pod yield showed positive significant association with harvest index (0.8177) and latent period (0.5263). The association was negative and significant with percent of leaves affected by LLS (-0.713), percent leaves affected by rust (-0.47), LLS severity (-0.651) and rust severity (-0.6232). (Table 4.4).

The association of plant height was positive and significant with percent of leaves affected by LLS (0.4488), percent of leaves affected by rust (0.3658), LLS severity (0.421) and rust severity (0.4059). Negative and significant association was observed with number of mature pods per plant (-0.544), number of immature pods per plant (-0.532), harvest index (-0.442).

Number of primary branches exhibited positive and significant association with number of immature pods per plant (0.3878) and shelling out-turn (0.3072). Number of mature pods per plant recorded a negative significant with LLS severity (-0.386). Harvest index showed negative and significant association with percent of leaves affected by LLS (-0.715), percent of leaves affected by rust (-0.463) and LLS severity (-0.594) and negative significant association with rust score (-0.5196).

4.4.1.3 Abhaya: Pod yield per plant showed positive significant association with mature pods per plant (0.7584), harvest index (0.84) and latent period (0.6485). Negative and significant association was observed with plant height (-0.3349), percent of leaves affected by LLS (-0.551), percent leaves affected by rust (-0.595), LLS severity (-0.837) and rust severity (-0.5591). (Table 4.5).

Plant height exhibited negative and significant association with latent period (-0.31). Positive and significant association was observed with percent of leaves affected by rust (0.5074) and LLS severity (0.3407). Number of primary branches per plant showed a positive and significant association with number of immature pods per plant (0.3312).

Number of mature pods per plant showed a positive significant association with harvest index (0.6304) and latent period (0.8508) and negative significant association with percent of leaves affected by LLS (-0.488), percent of leaves affected by rust (-0.632), LLS score (-0.58) and rust score (-0.4485).

Shelling out-turn showed positive and significant association with harvest index (0.3484). Harvest index showed negative and significant association with percent of leaves affected by rust (-0.396), LLS severity (-0.756) and rust severity (-0.3547). It showed positive significant association with latent period (0.4893).

4.4.1.4 Kadiri-6: In Kadiri-6, pod yield exhibited positive significant association with mature pods per plant (0.8025), harvest index (0.666) and latent period (0.679). It had negative significant association with LLS severity (-0.3242) and rust severity (-0.598). (Table 4.6).

Positive and significant association of plant height was recorded with percent of leaves affected with rust (0.3249). A negative significant association was observed with shelling out-turn (-0.048) and harvest index (-0.378). Positive and significant association of number of primary branches was recorded with number of immature pods per plant (0.4226).

Number of mature pods per plant showed a positive significant association with harvest index (0.4887) and latent period (0.7768) and negative significant association with percent of leaves affected by LLS (-0.444), LLS score (-0.3618) and rust score (-0.562). Shelling out-turn exhibited positive significant association with harvest index (0.1525). Harvest index showed negative significant association with percent of leaves affected by rust (-0.369) and rust severity (-0.502).

4.4.1.5 TLG-45: In TLG-45, a positive significant association was recorded between pod yield per plant and number of primary branches per plant (0.3921), mature pods per plant (0.7683), harvest index (0.7508) and latent period (0.4939). Negative and significant association was observed only with rust severity (-0.39). (Table 4.7).

Positive significant association of plant height was observed only with number of primary branches per plant (0.4467). Negative and significant association of number of primary branches per plant was recorded only with rust severity (-0.336).

Number of mature pods per plant showed positive significant association with harvest index (0.5341) and latent period (0.7033) and negative and significant association with rust severity (-0.313) and percent of leaves affected by rust (-0.31). Number of immature pods per plant showed negative significant association with shelling out-turn (-0.34) and harvest index (-0.4). Shelling out-turn recorded positive and significant association with harvest index (0.4324) Harvest index showed a significant positive association with latent period (0.334).

4.4.1.6 TCGS-876: In TCGS-876, there was a positive significant association between pod yield and plant height (0.5288), number of primary branches (0.5381), mature pods per plant (0.8458), harvest index (0.8197) and latent period (0.7561). Negative significant association was observed between pod yield and percent leaves percent leaves affected by rust (-0.3962), LLS severity (-0.473) and rust severity (-0.396) (Table 4.8).

Plant height had positive and significant association with number of primary branches per plant (0.4565), number of mature pods per plant (0.5465) and latent period (0.54) and negative and significant association with the percent of leaves affected by rust (-0.3343). Number of primary branches per plant showed a positive significant association with number of mature pods per plant (0.5772) and latent period (0.5412) and negative and significant association with LLS severity (-0.349).

Number of mature pods per plant exhibited positive and significant association with harvest index (0.6575) and latent period (0.8548) and negative and significant association with percent of leaves affected by rust (-0.3321), LLS severity (-0.352) and rust score (-0.488). Number of immature pods per plant showed a negative significant association with shelling out-turn (-0.316).

Shelling out-turn had positive significant association with harvest index (0.449) and negative significant association with LLS severity (-0.292). Harvest index exhibited a positive significant association with latent period (0.5099). It showed a negative and significant association with LLS severity (-0.478) and rust severity (-0.339).

4.4.1.7 GPBD-4: In GPBD-4, the common pollen parent, pod yield showed positive and significant association with plant height (0.4821), number of mature pods per plant (0.6325), number of immature pods per plant (0.4765) and harvest index (0.8669) (Table 4.3).

The association of plant height was positive and significant with number of mature pods per plant (0.541), number of immature pods per plant (0.5027), shelling out-turn (0.4287) and percent leaves affected by rust (0.3267). It was negative and significant with only rust severity (-0.379).

The association of number of mature pods per plant was found to be positive and significant with number of immature pods per plant (0.4027) and harvest index (0.3208) and negative and significant with LLS score (-0.379). Number of immature pods per plant exhibited positive and significant association with shelling out-turn (0.3518) and harvest index (0.33) and negative significant association with rust severity (-0.373).Shelling out-turn showed negative and significant association with LLS severity (-0.433). Harvest index had negative and significant association with rust severity (-0.462).

4.4.2 Character Association in Crosses

4.4.2.1 Tirupati-1 x GPBD-4: In the cross, Tirupati-1 x GPBD-4, the association between pod yield and mature pods per plant (0.8005), shelling out-turn (0.3531), harvest index (0.7072) and latent period (0.5553) was significant and in positive direction. It had significant negative correlation with percent of leaves affected by LLS (-0.4235), percent of leaves affected by rust (-0.4278), LLS score (-0.399) and rust score (-0.353). (Table 4.3).

Number of primary branches per plant showed positive and significant association with number of mature pods per plant (0.2683) and latent period (0.2189). Number of mature pods per plant exhibited positive and significant association with harvest index (0.5138) and latent period (0.7327) and negative and significant association with percent of leaves affected by LLS (-0.3178), percent of leaves affected by rust (-0.4423), LLS severity (-0.358) and rust severity (-0.348).

Positive significant association of number of immature pods per plant was recorded with rust severity (0.2264) and negative significant association with shelling out-turn (-0.311), percent of leaves affected by LLS (-0.2858), percent of leaves affected by rust (-0.1997).

Shelling out-turn recorded positive and significant association with harvest index (0.4706). Harvest index showed positive and significant association with latent period (0.3747) and negative and significant association with percent of leaves affected by LLS (-0.2968), percent of leaves affected by rust (-0.2681), late leaf score (-0.294) and rust score (-0.327).

4.4.2.2 Narayani x GPBD-4: Pod yield was found to have positive and significant association with mature pods per plant (0.7757), shelling out-turn

(0.4415), harvest index (0.7501), and latent period (0.6204). It showed significant negative association with percent of leaves affected by LLS (-0.5077), percent of leaves affected by rust (-0.1833), LLS severity (-0.5814) and rust severity (-0.5954) (Table 4.4).

Plant height had positive and significant association with number of mature pods per plant (0.195). Number of mature pods per plant had positive significant association with harvest index (0.4814) and latent period (0.8028) and negative significant association with percent of leaves affected by LLS (-0.3067), LLS severity (-0.4881) and rust severity (-0.5379). Number of immature pods per plant showed a positive significant association with percent of leaves affected by LLS (0.2237).

Shelling out-turn recorded positive and significant association with with harvest index (0.5808) and negative and significant association with percent of leaves affected by LLS (-0.5143), LLS severity (-0.3597) and rust severity (-0.2274). Harvest index showed a positive and significant association with latent period (0.3049). It exhibited negative and significant association with the percent of leaves affected by LLS (-0.6024), percent of leaves affected by rust (-0.253), LLS score (-0.4851) and rust score (-0.4282).

4.4.2.3 Abhaya x GPBD-4: In the cross, Abhaya x GPBD-4, pod yield recorded negative and significant association with LLS severity (-0.5255) and rust severity (-0.5288). Plant height exhibited positive significant association with number of mature pods per plant (0.237)(Table 4.5).

Number of primary branches per plant showed a positive significant association only with shelling out-turn (0.1825.) Number of mature pods per plant showed positive significant association with number of immature pods per plant (0.2527), shelling out-turn (0.2408), harvest index (0.4827) and latent period (0.8323) and negative significant association with percent of leaves affected by LLS (-0.3117).

The association of number of immature pods per plant was found to be positive and significant with shelling out-turn (0.2743), harvest index (0.2675) and latent period (0.208) and negative and significant with percent of leaves affected by LLS (-0.3532).

Shelling out-turn showed a positive and significant association with harvest index (0.5698) and percent of leaves affected by rust (0.1785) and negative significant association with percent of leaves affected by LLS (-0.1938). Harvest index showed significant negative association with percent leaves affected by LLS (-0.3253) The association was found to be positive and significant with percent leaves affected by rust (0.2977) and latent period (0.2538).

4.4.2.4 Kadiri-6 x GPBD-4: Positive significant association of pod yield was observed between mature pods per plant (0.854), harvest index (0.763) and latent period (0.6555). It showed negative significant association with percent of leaves affected by LLS (-0.215), LLS severity (-0.2724) and rust severity (-0.2114) (Table 4.6).

Plant height showed a significant negative association with number of primary branches per plant (-0.185) The association was found to be positive and significant association with percent of leaves affected by rust (0.3708). Number of primary branches per plant showed positive and significant association with number of mature pods per plant (0.2194) and negative and significant association with shelling out-turn (-0.191) and percent of leaves affected by rust (-0.2212).

Number of mature pods per plant recorded positive significant association with harvest index (0.5025) and latent period (0.8339); negative significant association with percent of leaves affected by LLS (-0.226), LLS score (-0.262) and rust score (-0.218). Number of immature pods per plant recorded positive significant association with percent of leaves affected by LLS (0.2196) and negative significant association with shelling out-turn (-0.221), harvest index (-0.291).

Shelling out-turn exhibited positive significant association with harvest index (0.4439) and percent of leaves affected by rust (0.2117) and negative and significant association with LLS severity (-0.2636). Harvest index had a positive significant association with harvest index and percent of leaves affected by rust (0.3535) and latent period (0.2777). It exhibited a negative and significant association with percent of leaves affected by LLS (-0.272), LLS severity (-0.2819) and rust severity (-0.2367).

4.4.2.5 TLG-45 x GPBD-4: Pod yield was found to be positively and significantly correlated with plant height (0.3476), number of primary branches per plant (0.2958), matured pods per plant (0.8216), harvest index and latent period (0.6927). Negative significant association was observed with percent of leaves affected by LLS (-0.3199) and percent leaves affected by rust (-0.2463). (Table 4.7).

Plant height showed negative and significant association with number of immature pods (-0.282) and shelling out-turn (-0.241). A positive and significant association was observed with number of mature pods per plant (0.3) and rust severity (0.3084). Number of primary branches per plant exhibited positive and significant association with number of mature pods per plant (0.315) and latent period (0.2953).

Number of mature pods per plant showed a positive significant association with harvest index (0.3824) and latent period (0.885) and negative significant association with percent of leaves affected by LLS (-0.2996), percent of leaves affected by rust (0.1957). The association of number of immature pods per plant was positive and significant with latent period (0.2583).

Shelling out-turn had a positive and significant association with harvest index (0.3904); negative and significant association with percent of leaves affected by LLS (-0.1769) and LLS score (-0.214). Harvest index had a positive and significant association with latent period (0.2664). The association was negative and significant with percent of leaves affected by LLS (-0.4966), percent of leaves affected by rust (-0.4503), LLS severity (-0.347).

4.4.2.6 TCGS-876 x GPBD-4: Pod yield showed a positive significant association with plant height (0.0486), number of primary branches (0.2339), mature pods per plant (0.8946), shelling out-turn (0.2276), harvest index (0.6383) and latent period (0.8692). Negative significant association was observed with immature pods per plant (-0.033), percent leaves affected by LLS (-0.1864) (Table 4.8).

Plant height showed a positive significant association with percent of leaves affected by LLS (0.1933). The association was found to be negative and significant with harvest index (-0.392) and rust severity (-0.2238). The association of number of primary branches per plant was observed to be positive and significant with number of mature pods per plant (0.2088).

Number of mature pods per plant had positive significant association with harvest index (0.5665) and latent period (0.9332). Immature pods per plant showed a negative significant association with shelling out-turn (-0.277) and harvest index (-0.179). Shelling out-turn showed a positive significant association with harvest index (0.4591) and negative and significant association with percent of leaves affected by LLS (-0.2709). Harvest index showed a positive and significant association with latent period (0.4899) and negative and significant association with percent of leaves affected by LLS (-0.2752).

4.4.3 Comparison of Correlations in Parents and F_2 Populations

Among the six F_2 populations studied, pod yield recorded significant positive correlation with mature pods per plant in all the crosses except Abhaya x GPBD-4; with plant height in only one cross, TLG-45 x GPBD-4; with primary branches in two crosses, TLG-45 x GPBD-4 and TCGS-876 x GPBD-4; with shelling out-turn in two crosses, Tirupati-1 x GPBD-4 and Narayani x GPBD-4; with harvest index in five crosses except in Abhaya x GPBD-4. It recorded significant negative correlations with percent of leaves affected by LLS in five crosses except in Abhaya x GPBD-4; with percent of leaves affected by rust in four crosses except in Abhaya x GPBD-4 and Kadiri-6 x

GPBD-4; with LLS severity (percent) and rust severity (percent) in four crosses except in TLG-45 x GPBD-4 and TCGS-876 x GPBD-4.

Among the parents studied, pod yield showed positive significant association with harvest index in all the seven parents; with mature pods per plant in all the parents except in Narayani; with plant height in TCGS-876 and GPBD-4; with primary branches per plant in TLG-45 and TCGS-876; with immature pods per plant in GPBD-4; with latent period in all the parents except in GPBD-4 and with shelling out-turn in Tirupati-1. It showed negative significant association with percent of leaves affected by LLS in Narayani and Abhaya ; with percent of leaves affected by rust in Narayani, Abhaya and TCGS-876; with plant height in one parent, Abhaya; with LLS severity in five parents except in GPBD-4 and TLG-45 and with rust severity in all parents except in GPBD-4.

Strong association of pod yield with mature pods per plant and harvest index in five crosses and six parents except Narayani (mature pods had a non-significant positive association) indicates the scope for the simultaneous improvement of all these traits. In Abhaya x GPBD-4, the association was positive but not significant among the above mentioned traits indicating the possibility for independent selection and improvement in each trait. Significant association of mature pods per plant, shelling out-turn and harvest index in all the cross combinations is a good sign for simultaneous improvement of all these traits and improvement of pod yield through these traits. Among the foliar disease resistance parameters, latent period exhibited positive correlation with pod yield in five crosses and six parents except in GPBD-4 *i.e.* increase in latent period resulted in higher pod yield. It is quite clear that with the increase in latent period more leaf area would remain photosynthetically active for longer period. In the crosses, the association was not strong except in Narayani x GPBD-4. In Abhaya x GPBD-4 where the association was non-significant, this correlation had become weak which might be due to inherently high photosynthetic efficiency in the genotypes involved in the cross and hence no impact was seen with increase in latent period. In GPBD-4, the resistant parent, the association was not significant which might be again due to in built resistance and consequently there would be no loss in photosynthetically active leaf area.

Pod yield exhibited strong negative association with severity of LLS incidence and severity of rust incidence in all the parents except TLG-45 (correlation with severity of LLS incidence was non-significant) and GPBD-4 (correlation with both the characters were not significant). In the crosses, the magnitude (strength) of the association was lowered in comparison with the respective parents especially in TLG-45 x GPBD-4 and TCGS-876 x GPBD-4 where the associations were non-significant *i.e.* strong negative association between yield and resistance parameters was disrupted through recombination indicating the probability of getting high yielding segregants with high levels of resistance to foliar diseases in these cross combinations in later segregating generations. Percent of leaves affected by LLS and rust give a rough indication of reduction in photosynthetic efficiency due to development of necrotic areas and defoliation. In all the crosses, the association of pod yield with both these traits was negative and significant except in Abhaya x GPBD-4 (correlations with both the traits were not significant) and Kadiri-6 x GPBD-4 (correlations with percent of leaves affected by rust was not significant). Hence, in the cross Abhaya x GPBD-4 there is greater scope for getting segregants with lower percent of leaves affected by LLS or rust with high pod yield potential and thus, concurrent improvement of pod yield and disease resistance is possible.

Labana *et al.* (1980) recorded positive significant association between mature pods per plant and pod yield. Nagabhushanam *et al.* (1982a) and Raut *et al.* (2010) reported positive and significant correlation of shelling out-turn with pod yield. Among components of resistance to infection, latent period was found to be a reliable indicator of resistance as it was two days longer in resistant genotypes (Cantonwine *et al.* 2008)

Mature pods per plant exhibited significant positive correlation with plant height in three crosses, *viz.*, Narayani x GPBD-4, Abhaya x GPBD-4 and TLG-45 x GPBD-4; with primary branches in four crosses, Tirupati-1 x

GPBD-4, Kadiri-6 x GPBD-4, TCGS-876 x GPBD-4 and TLG-45 x GPBD-4; with immature pods per plant and shelling out-turn in only one cross, Abhaya x GPBD-4; with harvest index in all the crosses; with latent period in all crosses. Significant negative association was recorded with percent of leaves affected by LLS in five crosses except in TCGS-876 x GPBD-4; with percent of leaves affected by rust in two crosses, Tirupati-1 x GPBD-4 and TLG-45 x GPBD-4; with LLS severity in three crosses, Tirupati-1 x GPBD-4, Narayani x GPBD-4 and Kadiri-6 x GPBD-4.

Among parents, it showed positive significant association with plant height in TCGS-876, shelling out-turn in Tirupati-1; with harvest index in all parents except in Narayani; with immature pods per plant in GPBD-4; with latent period in four parents, Abhaya, Kadiri-6, TLG-45 and TCGS-876 and with percent of leaves affected by rust in Tirupati-1. It showed a negative significant association with plant height in Narayani; with percent of leaves affected by rust in Abhaya, TLG-45 and TCGS-876; with LLS severity in all parents except in TLG-45 and with severity of rust incidence in all the parents except in Narayani.

Mature pods per plant, a highly correlated trait with pod yield showed positive significant association with harvest index in all the crosses and in all the parents except in Narayani. In Narayani x GPBD-4, the association is positive and significant despite the non-significant association in the parent Narayani. In Narayani, biomass production was independent of partitioning efficiency and hence, source was strong which might be the main reason for good pod filling even under stress situation. The association with latent period was positive and significant in all the parents except Narayani and GPBD-4 while all the crosses including Narayani x GPBD-4 showed positive significant association. The association with shelling out-turn was negative and non-significant in all parents except Tirupati-1 (positive and significant) and all crosses except in Abhaya x GPBD-4. In the cross, Abhaya x GPBD-4, although both the parents had shown non-significant association, the cross showed a significant positive association. The number of mature pods per plant can be improved through harvest index, latent period and shelling out-turn. In short selection for harvest index and latent period might result in lines with higher number of mature pods per plant which in turn lead to yield improvement.

Mature pods per plant was found to negatively and significantly associated with severity of LLS in all the parents except in TLG-45. The association was significant in the crosses involving highly susceptible lines as female parents *i.e.* Tirupati-1 x GPBD-4, Narayani x GPBD-4 and Kadiri-6 x GPBD-4. In Abhaya x GPBD-4, TLG-45 x GPBD-4 and TCGS-876 x GPBD-4, the female parents are less susceptible than Narayani, Kadiri-6 and Tirupati-1. In combination with resistant parent, GPBD-4, the negative significant association with LLS severity had become non-significant. In segregating generations of these three crosses, there are greater chances of finding foliar disease resistant plants with higher number of mature pods per plant. Severity of rust incidence was negative and significant in all the parents except in Narayani while the association was non-significant in all the crosses indicating the scope for concurrent improvement of the number of mature pods per plant along with rust resistance.

Earlier, Parameswarappa *et al.* (2005) reported positive association of number of pods with shelling percent. Azad and Hamid (2000) reported positive significant association of mature pods with pod yield.

Shelling out-turn recorded significant positive correlation with harvest index in all the crosses; with mature pods per plant and primary branches in one cross, Abhaya x GPBD-4. It showed significant negative association with mature pods and immature pods per plant in one cross, Tirupati-1 x GPBD-4; with immature pods per plant in Kadiri-6 x GPBD-4 and TCGS-876 x GPBD-4; with plant height in TLG-45 x GPBD-4 and TCGS-876 x GPBD-4; with percent of leaves affected by LLS in four crosses except in Tirupati-1 x GPBD-4 and Kadiri-6 x GPBD-4; with percent of leaves affected by rust in two crosses Abhaya x GPBD4 and Kadiri-6 x GPBD-4; with primary branches in Kadiri-6 x GPBD-4; with LLS severity in three crosses, Narayani x GPBD-4, Kadiri-6 x GPBD-4 and TLG-45 x GPBD-4 and with rust severity in Narayani x GPBD-4 only.

Shelling out-turn recorded positive significant association with harvest index in four parents except in Narayani, Kadiri-6 and GPBD-4; with primary branches in Narayani; with plant height in GPBD-4; with percent of leaves affected by LLS in Kadiri-6 and with percent of leaves affected by rust in Tirupati-1. Negative significant association was exhibited with immature pods per plant in Tirupati-1, TLG-45 and TCGS-876 and severity of LLS in Tirupati-1 and GPBD-4.

These results are in accordance with the results obtained by Padmaja (1985), Seethala Devi (2004) and Sirisha (2005) who reported positive significant association between shelling percent and harvest index.

Shelling out-turn, the character that determines proportion of the kernel yield in total pod yield was found to have a positive significant association with harvest index in all the crosses while the association was non-significant in four parents *i.e.* Tirupati-1, Abhaya, TLG-45 and TCGS-876. It is quite obvious that there has been a strengthening of the association in crosses compared to the parents. It is desirable as a better proportion of the total biomass produced is utilized for the production of quality kernels in terms of weight.

Shelling out-turn showed a negative association with disease components in crosses compared to the parents. In *kharif* 2010, due to severe disease pressure, the mean shelling out-turn was reduced in all the parents when compared to their real potential in the absence of stress due to diseases. This was reflected in the crosses especially Narayani x GPBD-4, Kadiri-6 x GPBD-4 and TLG-45 x GPBD-4 where the association with LLS severity was significant. In Tirupati-1 x GPBD-4, there was a non-significant association with LLS severity even though both the parents, Tirupati-1 and GPBD-4 showed negative and significant association. This shows a weakened association in the cross which is desirable in developing resistant lines with shelling out-turn in later generations.

Harvest index exhibited positive significant association with mature pods per plant and shelling out-turn in all the crosses; with immature pods per plant in three crosses, Abhaya x GPBD-4, Kadiri-6 x GPBD-4 and TCGS-876 x GPBD-4 and negative significant association with plant height in only one cross, TCGS-876 x GPBD-4.

In parents, it exhibited positive significant association with mature pods per plant except Narayani; with shelling out-turn in five parents except in Narayani and Kadiri-6; with latent period in Tirupati-1, Abhaya, TLG-45 and TCGS-876; with immature pods in GPBD-4 and with percent of leaves affected by rust in Tirupati-1. It showed negative significant association with plant height in Narayani, Abhaya and Kadiri-6; with immature pods in only one parent, Tirupati-1; with percent of leaves affected by LLS in Narayani; with percent of leaves affected by rust in Narayani, Abhaya and Kadiri-6; with severity of LLS in Tirupati-1, Narayani, Abhaya and GPBD-4 and with severity of rust in all parents except Tirupati-1 and TLG-45.

Harvest index, the most important indicator of partitioning efficiency was found to be positively and significantly associated with pod yield and the important yield contributing characters, mature pods per plant and shelling out-turn in all the crosses except Abhaya x GPBD-4 (where harvest index was non-significantly associated). Selection for the characters, harvest index and mature pods per plant together might be highly rewarding for yield improvement in these crosses.

The negative association of harvest index with the disease component characters observed in the parents was weakened in all the crosses which shows that there is a chance of developing resistant lines with high harvest index in later generations.

The results are in accordance with those obtained by John *et al*. (2005), Korat *et al*. (2010) who reported positive significant association of harvest index with pod yield. Hence, improvement in yield could be achieved through selection in terms of harvest index.

Latent period showed significant positive association with mature pods per plant and harvest index in all the crosses and with primary branches in two crosses, Tirupati-1 x GPBD-4 and TLG-45 x GPBD-4. Percent of leaves affected by LLS exhibited significant negative correlation with harvest index in all the crosses; with mature pods per plant in five crosses except in TCGS-876 x GPBD-4; with immature pods per plant in four crosses, Tirupati-1 x GPBD-4, Narayani x GPBD-4, Abhaya x GPBD-4 and Kadiri-6 x GPBD-4; with shelling out-turn in four crosses, Narayani x GPBD-4, Abhaya x GPBD-4, TLG-45 x GPBD-4 and TCGS-876 x GPBD-4, significant positive association with plant height in TCGS-876 x GPBD-4; with percent of leaves affected by rust in two crosses, Tirupati-1 x GPBD-4 and TLG-45 x GPBD-4; with LLS severity in three crosses, Tirupati-1 x GPBD-4, Narayani x GPBD-4 and TLG-45 x GPBD-4 and rust severity in three crosses, Narayani x GPBD-4, Kadiri-6 x GPBD-4 and TLG-45 x GPBD-4.

Latent period exhibited positive significant association with pod yield in all parents except in GPBD-4; with harvest index in four parents except in Narayani, Tirupati-1 and GPBD-4; with plant height and primary branches in TCGS-876. It showed negative significant association with percent of leaves affected by LLS in Narayani, Abhaya and Kadiri-6; with percent of leaves affected by rust in Narayani, Abhaya, TLG-45, TCGS-876 and GPBD-4; with severity of LLS in Tirupati-1, Abhaya and Kadiri-6 and with rust incidence in Tirupati-1, Abhaya and Kadiri-6.

Cantonwine *et al.* (2008) assessed components of resistance in three runner-type peanut cultivars to infection by *Cercosporidium personatum* and reported that latent period was larger by two days longer in resistant genotypes. Joel *et al.* (2006) reported that incubation period and number of functional leaves are positively and significantly associated with pod yield.

LLS severity showed significant negative correlation with mature pods per plant in three crosses, Tirupati-1 x GPBD-4, Narayani x GPBD-4 and Kadiri-6 x GPBD-4; with harvest index in four crosses, Tirupati-1 x GPBD-4, Narayani x GPBD-4, Kadiri-6 x GPBD-4 and TLG-45 x GPBD-4; with shelling out-turn in three crosses, Narayani x GPBD-4, Kadiri-6 x GPBD-4 and TLG-45 x GPBD-4; with latent period in Tirupati-1 x GPBD-4 and Narayani x GPBD-4 and significant positive correlation with percent of leaves affected by LLS in Tirupati-1 x GPBD-4, Narayani x GPBD-4 and TLG-45 x GPBD-4; with percent of leaves affected by rust in Tirupati-1 x GPBD-4 and TLG-45 x GPBD-4.

Severity of LLS showed negative significant association with mature pods per plant in all parents except in TLG-45, with pod yield in five parents except in GPBD-4 and TLG-45; with harvest index in Tirupati-1, Narayani, Abhaya and TCGS-876; with latent period in Tirupati-1 and positive significant association with plant height in Narayani and Abhaya; with immature pods per plant in Tirupati-1; with percent of leaves affected by by LLS in Narayani, Abhaya and Kadiri-6 and with severity of rust incidence in five parents except Tirupati-1 and TCGS-876.

Hassan and Beute (1977) concluded that a visual estimate of percent of leaves with leaf spots was an efficient evaluation method when large numbers of entries are to be tested for resistance to foliar diseases and that there exists a significant negative correlation. The negative association of percent of leaves affected by LLS was earlier reported by Giri *et al.* (2009).

Rust severity recorded significant negative correlation with mature pods per plant in Tirupati-1 x GPBD-4, Narayani x GPBD-4 and Kadiri-6 x GPBD-4; with harvest index in Tirupati-1 x GPBD-4, Narayani x GPBD-4 and Kadiri-6 x GPBD-4; with shelling out-turn in Narayani x GPBD-4; significant positive correlation with percent of leaves affected by LLS in Narayani x GPBD-4, Kadiri-6 x GPBD-4 and TLG-45 x GPBD-4; with percent of leaves affected by rust in Tirupati-1 x GPBD-4 and TLG-45 x GPBD-4.

Severity of rust showed significant negative correlation with pod yield in all parents except GPBD-4; with harvest index in five parents except Tirupati-1 and Kadiri-6; with mature pods in all parents except Narayani; with plant height in Tirupati-1, Narayani and GPBD-4; with primary branches in TLG-45 and with latent period in Tirupati-1, Abhaya and Kadiri-6 and significant positive correlation with severity of LLS in Narayani, Abhaya, Kadiri-6, TLG-45 and GPBD-4; with percent of leaves affected by LLS in Narayani and Abhaya and with percent of leaves affected by rust in Narayani.

In some crosses, change in magnitude and in the direction of correlations was observed in crosses in comparison with their respective parents. In Narayani, shelling out-turn exhibited negative association with pod yield while in the cross Narayani x GPBD-4, the association was positive and significant. In Kadiri-6 and GPBD-4, the association between pod yield and percent of leaves affected by rust was negative and non-significant while in Kadiri-6 x GPBD-4, the association was positive. In the cross, Abhaya x GPBD-4, both the parents showed negative significant association between mature pods and LLS severity while in the F_2 population it was positive and non-significant which indicates scope for isolation of resistant lines in segregating generations. Similarly in crosses Abhaya x GPBD-4 and TLG-45 x GPBD-4, the association between mature pods and rust severity was negative and significant in both the female parents and negative and non-significant in GPBD-4 while the cross showed positive non-significant association. The association between shelling out-turn and rust severity was negative and non-significant in both the parents of the cross Abhaya x GPBD-4 while in the F_2, it has become positive and non-significant association. In crosses, Abhaya x GPBD-4 and Kadiri-6 x GPBD-4, the association between percent of leaves affected by rust and harvest index was negative and significant in both the female parents while the association had become positive and significant in the F_2 populations. In TCGS-876 x GPBD-4, the association between harvest index and rust severity was negative and significant in both the parents while F_2 showed a positive non-significant association. Some of the associations that have changed in F_2 population might have resulted through recombination in F_1. Some of these changes in F_2 population are useful in that they indicate the scope of deriving segregants with novel combination of characters unlike in parents *i.e.* in Abhaya x GPBD-4 negative significant association between mature pods and LLS severity in parents had become positive and non-significant.

4.5 INHERITANCE STUDIES

4.5.1 LLS resistance: The most important foliar diseases causing severe yield losses in groundnut are LLS caused by *Phaeoisariopsis personata* and rust caused by *Puccinia arachidis*. Reduction in yield varied from 50-70 percent (Jogloy *et al*. 1988). If this loss in yield could be prevented by incorporating optimum level of resistance into a high yielding variety, such as Narayani, considerable stability in yield can be achieved. Therefore hybridization programmes in groundnut are now aimed at incorporating resistance for these diseases into the established varieties. It is easy to incorporate resistance if genetic control of resistance is known.

The inheritance of late leaf spot resistance was studied in six groundnut crosses. In *kharif* 2010, the severity of late leaf spot was very high. The common pollen parent, GPBD-4, which is resistant to LLS recorded a mean score of three in the 1-9 point scale. All the ovule parents showed high susceptibility with a mean score of eight (TPT-1, Narayani and Kadiri-6) and seven (Abhaya, TLG-45 and TCGS-876). (Table 4.9)

The F_1s in all the crosses were highly susceptible indicating that susceptibility is dominant over resistance. The F_2 behaviour presented a good fit to the phenotypic ratio of 9:1 in all the crosses.

According to Demerec (1923), 9:1 ratio is a modified 15:1 ratio. This modification is due to linkage of duplicate genes. Coupling phase linkage between two duplicate genes would tend to make the ratio smaller. The ratio may be modified between the limits of 15:1 and 3:1 according to the closeness of linkage. On the contrary, repulsion phase linkage, between two duplicate genes would tend to increase the ratio between the limits of 15:1 and 1:0. The 9:1 ratio may be a result of coupling between two duplicate genes with about 36.9 percent of crossing over between them.

Table 4.9.Segregation for late leaf spot resistance in six crosses of groundnut

Crosses	F_1 behaviour	F_2 behaviour				
		No. of plants with high susceptibility	No. of plants with moderate susceptibility	Ratio	Probability %	Chi - square
Tirupati 1 x GPBD 4	Highly susceptible	196	23	9:1	80-90	0.0501
Narayani x GPBD 4	Highly susceptible	206	25	9:1	50-70	0.1931
Abhaya x GPBD 4	Highly susceptible	191	22	9:1	80-90	0.0532
Kadiri 6 x GPBD 4	Highly susceptible	176	23	9:1	50-70	0.4416
TLG 45 x GPBD 4	Highly susceptible	211	20	9:1	50-70	0.3958
TCGS 876 x GPBD 4	Highly susceptible	201	26	9:1	50-70	0.4354

Table 4.10.Segregation for rust resistance in three crosses of groundnut

Crosses	F_1 behaviour	F_2 behaviour				
		No. of plants with moderate susceptibility	No. of plants with low susceptibility	Ratio	Probability %	Chi - square
Tirupati 1 x GPBD 4	Moderately susceptible	212	15	15:1	70-80	0.07612
Narayani x GPBD 4	Moderately susceptible	217	16	15:1	70-80	0.07126
Kadiri 6 x GPBD 4	Moderately susceptible	201	12	15:1	70-80	0.0819

Nevill (1980) also proposed that genes at three or four loci controlled the disease resistance from the studies in the F_2 of a cross between Robout 33-1 and Karpovikas 16. A genetic system involving five loci was proposed by Nevill (1982) from his studies in five F_2 populations from crosses between three resistant lines (*Arachis hypogaea* subsp. *fastigiata* var *fastigiata*) and three susceptible cultivars (two of *Arachis hypogaea* subsp. *fastigiata* var *vulgaris* and one of *Arachis hypogaea* var *hypogaea*) in which the susceptible material was used as female parent. Resistant material is homozygous recessive at loci 1, 2, 3 and 4, susceptible Robout 33-1 is homozygous recessive at loci 3, 4 and 5, and susceptible TMV-2 has no resistant genes.

The genotypic formulae have not been assigned as the present study was undertaken to have only preliminary information on inheritance without back crosses or test crosses or F_3 population study to confirm the results observed in F_2. The result presented are in accordance with the previous reports of Sharief (1972), Soriano (1988) and Vasanthi and Raja Reddy (1997) indicating that resistance is recessive and that it is governed by two duplicate genes.

4.5.2 Rust resistance: The inheritance of rust was studied in six groundnut crosses. (Table 4.10). The common pollen parent, GPBD-4 was resistant to rust with a mean score of 1.97 in the 1-9 point scale. The ovule parents, Narayani, Kadiri-6 and Tirupati-1, also showed susceptibility with a mean score between 2.20 and 2.77. The F_1s were as susceptible as female parents and its behaviour was uniform in the crosses Narayani x GPBD-4, Kadiri-6 x GPBD-4 and Tirupati-1 x GPBD-4. The F_2 plants of these three crosses were classified on the basis of susceptibility score of the parents involved. The F_2 population presented a good fit to phenotypic ratio of 15:1 in all the crosses.

It can be hypothesized that the ovule parents possess two homozygous dominant alleles while the pollen parent possesses two recessive alleles and two genes are not linked to each other. Genotypic formulae are not assigned as only F_2 population was studied with no back crosses or test crosses.

The results are in complete agreement with the results presented by Bromfield and Bailey (1972), Nigam *et al*. (1980), Vindhiyavarman *et al*. (1993) and Vasanthi and Raja Reddy (1997) stating that rust resistance is recessive to susceptibility and controlled by two genes.

4.5.3 Transgressive segregation: The appearance in the F_2 (or later) generation of individuals showing a more extreme development of a character than either parents is termed as transgressive segregation. It is attributed to cumulative and complementary effects of genes contributed by the parents of the cross. The transgressive segregates that exceed the best parent of a cross can be fixed through inbreeding and selection as shown by Smith (1952) working with intervarietal hybrids of the autogamous cultivated species of *Nicotiana rustica*. The manipulation of such segregates could be the best way to exploit diverse sources of genes for increasing yield.

In the present study, transgressive segregants were identified by finding the number of plants exceeding mean value of the higher parent or lagging behind the mean value of the lower parent by critical difference at 5 percent level. The number of such plants that fitted this definition among all the six crosses is presented in Table. 4.11

F_2 plants that surpassed the parental limits were observed in all the crosses for plant height, number of primary branches, mature pods per plant, immature pods per plant, shelling out-turn, harvest index, percent of leaves affected by LLS (lower extreme segregants not observed), percent of leaves affected by rust (only very few lower extreme segregants were observed), latent period (higher extreme segregants in three crosses), LLS severity at 90 DAS (percent) (lower extreme segregants are rare), rust severity and pod weight per plant.

Number of transgressive segregants towards taller side was more than towards shorter side. Highest number of tall segregants were observed in TCGS-876 x GPBD-4 (54) followed by Narayani x GPBD-4 (50) and Abhaya x GPBD-4 (46) while it was low in Kadiri-6 x GPBD-4 (18). Highest number of

Table 4.11.Transgressive segregants for 12 characters in the F_2 population of six groundnut crosses

Trait / Cross	F_2 generation		Parents		No. of transgressive segregants	
	Highest plant value	Lowest plant value	Higher value	Lower value	Higher than higher parent	Lower than lower parent
Plant height (cm)						
Tirupati 1 x GPBD 4	66	31	42	37	22	15
Narayani x GPBD 4	73	35	50	37	50	3
Abhaya x GPBD 4	58	22	37	33	46	13
Kadiri 6 x GPBD 4	60	30	45	37	18	15
TLG 45 x GPBD 4	58	17	37	24	33	4
TCGS 876 x GPBD 4	61	31	39	37	54	3
Primary branches per plant						
Tirupati 1 x GPBD 4	6	2	5	4	3	5
Narayani x GPBD 4	6	3	4	4	30	1
Abhaya x GPBD 4	6	4	4	4	16	0
Kadiri 6 x GPBD 4	6	2	4	4	30	3
TLG 45 x GPBD 4	6	3	4	4	40	3
TCGS 876 x GPBD 4	6	2	5	4	6	3
Mature pods per plant						
Tirupati 1 x GPBD 4	20	2	11	9	28	35
Narayani x GPBD 4	22	1	11	7	22	30
Abhaya x GPBD 4	23	0	11	11	38	41
Kadiri 6 x GPBD 4	19	1	11	7	10	37
TLG 45 x GPBD 4	35	0	11	9	41	29
TCGS 876 x GPBD 4	33	2	11	10	33	42

Contd......

Trait / Cross	F_2 generation		Parents		No. of transgressive segregants	
	Highest plant value	Lowest plant value	Higher value	Lower value	Higher than higher parent	Lower than lower parent
Immature pods per plant						
Tirupati 1 x GPBD 4	10	0	6	3	8	37
Narayani x GPBD 4	13	0	4	3	25	36
Abhaya x GPBD 4	16	0	4	3	38	19
Kadiri 6 x GPBD 4	8	0	3	3	31	28
TLG 45 x GPBD 4	19	1	11	3	8	4
TCGS 876 x GPBD 4	12	1	3	3	40	23
Shelling out turn (%)						
Tirupati 1 x GPBD 4	80	42	65	49	39	5
Narayani x GPBD 4	76	16	67	49	23	15
Abhaya x GPBD 4	79	0	65	49	18	18
Kadiri 6 x GPBD 4	78	33	68	49	42	7
TLG 45 x GPBD 4	78	26	69	49	10	17
TCGS 876 x GPBD 4	79	33	65	49	26	13
Harvest index (%)						
Tirupati 1 x GPBD 4	55	12	36	26	15	28
Narayani x GPBD 4	61	2	33	26	15	50
Abhaya x GPBD 4	44	0	44	26	5	31
Kadiri 6 x GPBD 4	54	6	37	26	23	31
TLG 45 x GPBD 4	69	9	50	26	10	13
TCGS 876 x GPBD 4	81	5	42	26	17	36

Contd......

Trait / Cross	F_2 generation		Parents		No. of transgressive segregants	
	Highest plant value	**Lowest plant value**	**Higher value**	**Lower value**	**Higher than higher parent**	**Lower than lower parent**
Percentage of leaves affected by LLS						
Tirupati 1 x GPBD 4	100	62	94	43	37	0
Narayani x GPBD 4	100	70	96	43	13	0
Abhaya x GPBD 4	99	76	80	43	85	0
Kadiri 6 x GPBD 4	100	85	95	43	50	0
TLG 45 x GPBD 4	99	66	78	43	56	0
TCGS 876 x GPBD 4	99	74	67	43	89	0
Percentage of leaves affected by rust						
Tirupati 1 x GPBD 4	100	0	78	15	60	2
Narayani x GPBD 4	94	0	85	15	14	1
Abhaya x GPBD 4	91	0	48	15	87	2
Kadiri 6 x GPBD 4	98	43	82	15	31	0
TLG 45 x GPBD 4	85	51	42	15	89	0
TCGS 876 x GPBD 4	59	51	55	15	42	0
Latent period						
Tirupati 1 x GPBD 4	3	1	6	1	0	0
Narayani x GPBD 4	2	1	6	1	0	0
Abhaya x GPBD 4	5	1	6	2	0	38
Kadiri 6 x GPBD 4	3	1	6	1	0	0
TLG 45 x GPBD 4	7	1	6	2	1	31
TCGS 876 x GPBD 4	7	1	6	2	1	47

Contd.......

Trait / Cross	F_2 generation		Parents		No. of transgressive segregants	
	Highest plant value	Lowest plant value	Higher value	Lower value	Higher than higher parent	Lower than lower parent
Late leaf spot score at 90 DAS (%)						
Tirupati 1 x GPBD 4	9	6	8	5	43	0
Narayani x GPBD 4	9	6	8	5	28	0
Abhaya x GPBD 4	9	5	7	5	35	0
Kadiri 6 x GPBD 4	9	5	8	5	11	0
TLG 45 x GPBD 4	9	4	7	5	42	1
TCGS 876 x GPBD 4	8	6	7	5	27	0
Rust score at 90 DAS (%)						
Tirupati 1 x GPBD 4	5	1	3	2	17	22
Narayani x GPBD 4	9	2	2	2	71	0
Abhaya x GPBD 4	4	1	2	2	22	27
Kadiri 6 x GPBD 4	5	1	3	2	7	5
TLG 45 x GPBD 4	5	1	2	2	27	25
TCGS 876 x GPBD 4	5	1	2	2	34	21
Pod weight per plant (g)						
Tirupati 1 x GPBD 4	10.17	0.64	5.53	4.91	26	39
Narayani x GPBD 4	11.16	0.15	5.03	4.91	22	42
Abhaya x GPBD 4	18.49	0.96	7.78	4.91	34	24
Kadiri 6 x GPBD 4	10.99	0.52	5.66	4.91	26	41
TLG 45 x GPBD 4	18.49	0.96	7.65	4.91	33	24
TCGS 876 x GPBD 4	24.24	0.97	7.86	4.91	25	31

short segregants were recorded in two crosses, Tirupati-1 x GPBD-4 (15) and Kadiri-6 x GPBD-4 (15) while short segregants were low in TLG-45 x GPBD-4 (4), Narayani x GPBD-4 (3) and TCGS-876 x GPBD-4 (3)

The number of primary branches per plant had highest number of higher extreme segregants in TLG-45 x GPBD-4 (40), Kadiri-6 x GPBD-4 (30) and Narayani x GPBD-4 (30) while lowest number was observed in Tirupati-1 x GPBD-4 (5), Kadiri-6 x GPBD-4 (3), TLG-45 x GPBD-4 (3) and TCGS-876 x GPBD-4 (3). There were no transgressive segregants observed in Abhaya x GPBD-4 (0) towards lower extreme. Lower extreme segregants were comparatively in smaller numbers.

For a quantitative trait that is highly correlated with pod yield, number of mature pods per plant, appearance of segregants surpassing better parent indicates the scope for yield improvement through fixing of the alleles in the transgressive segregants through inbreeding and selection. In three cross combinations, TLG-45 x GPBD-4 (41), Abhaya x GPBD-4 (38) and TCGS-876 x GPBD-4 (33), they appeared in larger number. Among these, in two of the crosses, the female parents, Abhaya and TCGS-876, have Virginia bunch parents in their pedigree. Monpara *et al*. (2004) observed greater proportion of transgressive segregants for pod yield per plant in inter - subspecific cross (JVR 391 x J11).

The transgressive segregants with higher number of immature pods per plant were high in the F_2 population of TCGS-876 x GPBD-4 (40) followed by Abhaya x GPBD-4 (38), Kadiri-6 x GPBD-4 (31) and Narayani x GPBD-4 (25) while they were low in Tirupati-1 x GPBD-4 (8) and TLG-45 x GPBD-4 (8). Transgressive segregants with lower number of immature pods per plant was high in Tirupati-1 x GPBD-4 (37), Narayani x GPBD-4 (36), Kadiri-6 x GPBD-4 (28) and TCGS-876 x GPBD-4 (23) while it was low in TLG-45 x GPBD-4 (4).

Transgressive segregants for higher shelling out-turn were more in Kadiri-6 x GPBD-4 (42), Tirupati-1 x GPBD-4 (39) and TCGS-876 x GPBD-4 (26) while it was low in Abhaya x GPBD-4 (18) and TLG-45 x GPBD-4 (10).

The frequency of transgressive segregants for low shelling out-turn was observed to be high in Abhaya x GPBD-4 (18), TLG-45 x GPBD-4 (17), Narayani x GPBD-4 (15) and TCGS-876 x GPBD-4 (13) while it was low in Kadiri-6 x GPBD-4 (7) and Tirupati-1 x GPBD-4 (5).

Number of transgressive segregants towards high harvest index were more in Kadiri-6 x GPBD-4 (23), TCGS-876 x GPBD-4 (17), Tirupati-1 x GPBD-4 (15) and Narayani x GPBD-4 (15) while it was low in Abhaya x GPBD-4 (5). Highest number of low harvest index transgressive segregants were observed in Narayani x GPBD-4 (50), TCGS-876 x GPBD-4 (36), Abhaya x GPBD-4 (31) and Kadiri-6 x GPBD-4 (31) while they were low in TLG-45 x GPBD-4 (13).

More number of higher extreme segregants for percent of leaves affected by LLS were observed in TCGS-876 x GPBD-4 (89), Abhaya x GPBD-4 (85), TLG-45 x GPBD-4 (56) and Kadiri-6 x GPBD-4 (50) while they were low in Narayani x GPBD-4 (13). There were no lower extreme segregants for this trait in any of the crosses.

More number of higher extreme segregants for percent of leaves affected by rust were recorded in TLG-45 x GPBD-4 (89), Abhaya x GPBD-4 (87) and Tirupati-1 x GPBD-4 (60) while its number was low in Narayani x GPBD-4 (14). Lower extreme segregants were observed only in Tirupati-1 x GPBD-4 (2), Abhaya x GPBD-4 (2) and Narayani x GPBD-4 (1).

Transgressive segregants with longer latent period were observed only in TLG-45 x GPBD-45 (1) and TCGS-876 x GPBD-4 (1) while transgressive segregants with shorter latent period were observed in TCGS-876 x GPBD-4 (47), Abhaya x GPBD-4 (38) and TLG-45 x GPBD-4 (31) only.

Transgressive segregants for high LLS severity at 90 DAS were observed to be high in Tirupati-1 x GPBD-4 (43), TLG-45 x GPBD-4 (42) and Abhaya x GPBD-4 (35) while they were low in Kadiri-6 x GPBD-4 (11). Only one segregant was observed in TLG-45 x GPBD-4.

Number of transgressive segregants with high rust severity were more in Narayani x GPBD-4 (71), TCGS-876 x GPBD-4 (34) and TLG-45 x GPBD-4

(27) while they were low in Kadiri-6 x GPBD-4 (7). Frequency of transgressive segregants for low rust severity was high in Abhaya x GPBD-4 (27), TLG-45 x GPBD-4 (25), TCGS-876 x GPBD-4 (21) and Tirupati-1 x GPBD-4 (22) while it was low in Kadiri-6 x GPBD-4 (5) and nil in Narayani x GPBD-4.

Most noteworthy was the transgressive segregation for higher pod weight per plant as the character is of economic importance. The number of transgressive segregants with higher pod yield was more in Abhaya x GPBD-4 (34), TLG-45 x GPBD-4 (33), Tirupati-1 x GPBD-4 (26) and Kadiri-6 x GPBD-4 (26) and they were low in Narayani x GPBD-4 (22). Transgressive segregants with lower pod yield were high in Narayani x GPBD-4 (42), Kadiri-6 x GPBD-4 (41) and Tirupati-1 x GPBD-4 (39) and they were low in Abhaya x GPBD-4 (24) and TLG-45 x GPBD-4 (24)

According to Monpara *et al.* (2004), the occurrence of transgressive segregation is evidence for multiple factor control of a trait, and that the parents contribute different alleles towards expression of a trait. The fact that the transgressive segregation occurred for all traits in the present study shows that the parents used in the study are diverse and might have contributed different alleles. The fact that the extreme parental types and transgressive individuals were captured within a population of 250 to 300 F_2 plants is an indication that the traits may probably be governed by a fewer genes under the influence of several modifiers and is not a polygenic trait. Many characters in groundnut have been reported to be oligogenic that show quasi-quantitative inheritance. Quasi-quantitative inheritance is mainly recognizable by the existence of more than two stable phenotypes (Gruneberg, 1952) and characteristic mixing features for both quantitative and qualitative traits resulting in conflicting results as to the type of inheritance involved.

a

b

c

Fig 4.1 Defoliation in Tirupati-1 x GPBD-4 F_2 plant in comparison with its parents a.Tirupati-1, b. GPBD-4, c. Tirupati-1 x GPBD-4.

a

b

c

Fig 4.2 Defoliation in Narayani x GPBD-4 F_2 plant in comparison with its parents a. Narayani, b. GPBD-4, c. Narayani x GPBD-4.

a

b

c

Fig 4.3 Defoliation in Abhaya x GPBD-4 F_2 plant in comparison with its parents a. Abhaya, b. GPBD-4, c. Abhaya x GPBD-4.

a

b

c

Fig 4.4 Defoliation in Kadiri-6 x GPBD-4 F_2 plant in comparison with its parents a. Kadiri-6, b. GPBD-4, c. Kadiri-6 x GPBD-4.

a 

b 

c 

Fig 4.5 Defoliation in TLG-45 x GPBD-4 F_2 plant in comparison with its parents a. TLG-45, b.GPBD-4, c. TLG-45 x GPBD-4 .

a 

b 

c 

Fig 4.6 Defoliation in TCGS-876 x GPBD-4 F_2 plant in comparison with its parents a. TCGS-876, b. GPBD-4, c. TCGS-876 x GPBD-4.

Chapter ~ V

Summary and Conclusions

CHAPTER V

SUMMARY AND CONCLUSIONS

The present study entitled **"Genetic studies in the F_2 populations of six groundnut (*Arachis hypogaea* L.) crosses"** was undertaken to elicit information on i) heritability, variability and genetic advance for late leaf spot and rust resistance, morphological traits, yield and yield attributes in F_2 generation of six crosses, ii) correlation between late leaf spot and rust resistance and yield and yield attributes in F_2 populations of six groundnut crosses, iii) inheritance of late leaf spot and rust resistance.

The experimental material consisted of seven parents *viz*., Tirupati-1, Narayani, Abhaya, Kadiri-6, TLG-45 and TCGS-876 and six F_2 populations involving above said parents where GPBD-4 was common male parent. The crop was grown during *kharif* 2010 at dryland farm of Regional Agricultural Research Station (RARS), Tirupati in a randomized block design with three replications.

Data was recorded for the characters, plant height, number of primary branches per plant, number of mature pods per plant, number of immature pods per plant, shelling out turn, harvest index, percent of leaves affected by late leaf spot, percent of leaves affected by rust, latent period for late leaf spot from inoculation to first appearance of symptom, late leaf spot score at 90 days after sowing, rust score at harvest and pod yield per plant.

Significant differences among crosses and parents were observed for all the characters studied. Mean values of pod yield, mature pods per plant, harvest index and number of primary branches were high in TLG-45 x GPBD-4, TCGS-876 x GPBD-4 and Abhaya x GPBD-4. Mean shelling out-turn was high in crosses, Tirupati-1 x GPBD-4, Kadiri-6 x GPBD-4 and TCGS-876 x GPBD-4. With regard to foliar disease resistance parameters, lower mean values for percentage of leaves affected by LLS, rust and LLS and rust severity were recorded in TLG-45 x GPBD-4, TCGS-876 x GPBD-4 and Abhaya x GPBD-4 and higher mean latent period was also registered in these three crosses.

Genotypic coefficient of variation, heritability and genetic advance as percentage of the mean were relatively high for pod yield, mature pods per plant, immature pods per plant and primary branches per plant in four crosses, Abhaya x GPBD-4, TLG-45 x GPBD-4, Narayani x GPBD-4 and TCGS-876 x GPBD-4. For harvest index, moderate values of GCV, heritability and GAM were recorded in only one cross, TCGS-876 x GPBD-4. In these crosses, these characters appear to be highly influenced by additive gene action and simple phenotypic selection would be effective for the improvement of these traits. In the cross, TLG-45 x GPBD-4, higher values of GCV, heritability and GAM were recorded for latent period. For LLS and rust severity, genetic parameters were high in Tirupati 1 x GPBD-4 and Narayani x GPBD-4 in which female parents were highly susceptible to LLS and rust. In these crosses, selection for disease resistance would be effective in early generations. In Abhaya x GPBD-4, selection for LLS resistance would be more fruitful in early generations. Considerable variation was observed for percentage of leaves affected by rust in five crosses except in TCGS-876 x GPBD-4.

In majority of the crosses, there was significant positive association of pod yield with harvest index, mature pods per plant and latent period and significant negative association with percent of leaves affected by LLS, rust and severity of LLS and rust. Abhaya x GPBD-4 showed non-significant negative association with percent of leaves affected by LLS and rust. The association of pod yield per plant with LLS and rust severity was negative and non-significant in the crosses, TL-45 x GPBD-4 and TCGS-876.Harvest index showed a positive significant association with mature pods per plant and shelling out-turn. In respect of certain character pairs, correlations that were found to be negative in the parents became positive in the F_2 generation and also there were differences in the magnitude (strength) of correlations *i.e.*, between pod yield and shelling out-turn in Narayani x GPBD-4, between mature pods and LLS severity in Abhaya x GPBD-4 and TLG-45 x GPBD-4, between mature pods and rust severity in Abhaya x GPBD-4, between shelling out-turn and rust severity in Abhaya x GPBD-4 and Kadiri-6 x GPBD-4 and between harvest index and rust severity in TCGS-876 x GPBD-4. This might be due to altered linkage relations due to recombination and segregation.

Preliminary studies on inheritance of late leaf spot resistance considering the entire population data of six F_2 populations indicate that the trait may be governed by two recessive genes with duplicate gene action with F_2 phenotypic ratio of 9 susceptible: 1 moderately susceptible in all the crosses. The ratio obtained may be due to coupling phase linkage between the two genes.

Segregation pattern of inheritance of rust resistance in the crosses Narayani x GPBD-4, Kadiri-6 x GPBD-4 and Tirupati-1 x GPBD-4 indicated that the character is governed by two genes acting in duplicate manner. An F_2 phenotypic ratio of 15 moderately susceptible : 1 resistant was noticed in these three crosses.

From the results obtained in the present study the following conclusions can be drawn:

- TLG-45 x GPBD-4, TCGS-876 x GPBD-4 and Abhaya x GPBD-4 are the crosses that appear promising and can be studied in greater detail in later segregating generations for isolation of useful recombinants with high yield and high levels of resistance to foliar diseases.
- Selection would be rewarding in early generations for pod yield, mature pods per plant, harvest index, primary branches per plant, latent period and LLS and rust resistance as GCV, h^2 and GAM were found to be fairly high in certain crosses.

- Correlation studies indicated the scope of simultaneous improvement of pod yield, mature pods per plant, HI and shelling out-turn and the scope for exploiting altered relations for selection of lines with high yield potential and resistance to foliar diseases.
- As resistance was found to be recessive in nature for both LLS and rust, it is necessary to have large F_2 population to uncover resistant segregants.

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Appendix

APPENDIX

Analysis of Variance among six F_2 populations and their parents

S.No.	Character	Mean sum of squares		
		Replications (df = 2)	**Treatments (df = 12)**	**Error (df = 24)**
1.	Plant height (cm)	3.617	183.858**	13.653
2.	Primary branches per plant	0.023	0.150**	0.030
3.	Mature pods per plant	5.146	6.662**	1.672
4.	Immature pods per plant	2.697	14.909**	0.932
5.	Shelling out turn	16.895	32.965**	2.975
6.	Harvest index	18.897	67.764**	8.281
7.	Percentage of leaves affected by LLS	9.480	387.473**	5.165
8.	Percentage of leaves affected by rust	30.447	481.148**	12.171
9.	Latent period	0.066	3.856**	0.037
10.	Late leaf spot score at 90 DAS (1-9 scale)	41.200	135.567**	12.707
11.	Rust score at 90 DAS (1-9 scale)	9.082	88.679**	6.042
12	Pod weight (g)	3.971	4.265*	1.472

* Significant at P = 0.05
** Significant at P = 0.01