

**EVALUATION OF GROUNDNUT MUTANTS FOR
RESISTANCE TO *Spodoptera* AND THRIPS**

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AUGUST, 1997

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EVALUATION OF GROUNDNUT MUTANTS FOR RESISTANCE TO *Spodoptera* AND THRIPS

Thesis submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfilment of the requirements for the
Degree of

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By
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Certificate

This is to certify that the thesis entitled "EVALUATION OF GROUNDNUT MUTANTS FOR RESISTANCE TO *Spodoptera* AND THRIPS" submitted by Mr.M.N. RAJENDRA PRASAD for the degree of MASTER OF SCIENCE (Agriculture) in GENETICS AND PLANT BREEDING of the University of Agricultural Sciences, Dharwad, is a record of bonafide research work done by him during the period of his study in this university, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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Affectionately Dedicated
To My
Beloved Parents

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No scientific endeavour is a result of an individual's efforts.

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LIST OF ABBREVIATIONS USED

DAH	-	Days after hatching
DM	-	Days to maturity
DS	-	Damage due to <i>Spodoptera</i>
DT	-	Damage due to thrips
LDS	-	Number of leaflets damaged due to <i>Spodoptera</i>
LE	-	Number of lower (Abaxial) epidermal cells
LLS	-	Late leaf spot
MLP	-	Mean larval period
NT	-	Number of thrips
ODP	-	Ortho dihydroxy phenols
PP	-	Plant population
PY	-	Plant yield
R	-	Rust
SMK	-	Sound mature kernel per cent
SP	-	Shelling percentage
TC	-	Tannin content
TLE	-	Thickness of lower (Abaxial) epidermis along with cuticle
TP	-	Total phenols
TPP	-	Thickness of palisade parenchyma
TS	-	Total sugars
TTL	-	Thickness of total leaf
TUE	-	Thickness of upper (Adaxial) epidermis along with cuticle
TW	-	Test weight
UE	-	Number of upper (Adaxial) epidermal cells
YH	-	Yield per hectare

INTRODUCTION

I. INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is one of the most important oil seed crops in the world and presently cultivated in an area of 21.7 m ha with a total production of 25.89 m tonnes. Groundnut crop occupies 31.30 per cent of the total cropped area under oil seeds and accounts for 36.10 per cent of total oil seed production in India. Like in other developing countries the average yield in India hovers around 900kg/ha as against the average of 2995 kg/ha realised in USA (Anon., 1995). Low productivity in developing countries may be attributed to abiotic and biotic stresses affecting the crop. Among biotic stresses defoliating insect, *Spodoptera litura* (F.) has become a major pest in recent years, because of which yield losses are reported to be 13-71 per cent in the states of Karnataka and Andhra Pradesh (Amin, 1983). In India, transitional tract (Dharwad) has been identified as hot spot for *S.litura* during *Kharif* season, where yield loss in groundnut to the extent of 66.6 per cent was recorded (Kulkarni, 1989). At present, the pest is mainly controlled by insecticidal application. However, insecticides often fail to give economic returns because of their cost and improper use. The problem is more acute with *S.litura* because of its polyphagous nature, rapid multiplication and resistance developed to some commonly used insecticides (Ramakrishna *et al.*, 1984). Similarly in post rainy season, thrips attain the pest status in groundnut as, sap feeders or vectors of virus and cause wide spread damage, which induces the farmers often to apply insecticides. The integrated

management of these pests with biological agents and resistance breeding appears to be the best strategy.

Spanish bunch cultivars are the most popular cultivars in the transitional tract of Karnataka as they mature early and facilitate double cropping under rainfed conditions besides possessing desirable pod features. But all the cultivated varieties are susceptible to *S.litura*. Similarly the Spanish bunch varieties under cultivation are susceptible to thrips. Research efforts have been successful in identifying germplasm resistant to *S.litura* (ICGV 87165, ICGV 86350, ICGV 86031, GBFDS 272) and thrips (ICGV 86388, ICGV 86031, ICGV 86388, ICGV 86430, NC Ac 2242, NC Ac 2232, NC Ac 2214), but most of them possess some undesirable attributes like low shelling percentage due to thick shelled pods and late maturity by 10-15 days (Anon., 1981, 1984, 1985, 1986).

Hence, there is a strong need to develop and identify new germplasm combining high level of resistance to *S.litura* and thrips, early maturity, desirable pod and kernel features besides productivity in groundnut. On mutagenesis with Ethyl Methane Sulphanote (EMS) in our laboratory a valencia line (VL 1) yielded many foliar disease resistant, early maturing and erect bunch mutants (Sheshagiri, 1994), some of which also appeared to be resistant to *S.litura* and thrips.

Hence, a systematic evaluation of 22 mutants derived from VL 1 was taken up in order to effectively utilise these mutants in breeding programme, and to understand the nature of resistance. The present investigation envisages

- 1) To screen mutants for resistance to *Spodoptera litura* (F.) and thrips.
- 2) To evaluate selected groundnut genotypes against *Spodoptera litura* (F.) and thrips.
- 3) To study life history parameters of *Spodoptera litura* (F.) reared on selected genotypes and
- 4) To study the histological and biochemical basis of resistance to *Spodoptera litura* (F.) and thrips.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Groundnut is presently cultivated throughout the tropical and warmer temperature regions of the globe. One of the main reasons for the low productivity in groundnut in developing countries is the occurrence of biotic stresses. Many insects cause yield reductions in groundnut. The development of insect resistant/ tolerant cultivars is important in integrated pest management and for increased stability of yield, decreased costs of production due to reduced insecticide usage, decreased probability of environmental contamination from inappropriate use of insecticide and specific environments where damage by insects can create economic yield loss.

The literature pertaining to groundnut pests, importance of *Spodoptera litura* (F.) and thrips, role of integrated pest management, host plant resistance to insects in general and in particular to *S.litura* & thrips, biology and development of *S.litura* on different groundnut genotypes and mechanism of resistance to *S.litura* are presented in this chapter.

2.1 Groundnut pests

Groundnut is attacked by numerous pest species, which cause damage ranging from incidental feeding to near total plant destruction and yield loss. Groundnut ranked tenth for the number of pests among the 77 major crops listed by Van Emden (1980). It has been reported that groundnuts were attacked by more than 360 insect species. The damage incurred by insect pests varies among locations. Most pests are highly mobile and have a wide distribution.

Groundnut is attacked by soil insects, insects that live on the leaves and flowers, and post harvest insects among which insects that live on the leaves and flowers are important, as they cause maximum yield loss when compared to others.

In India over 70 insects have been reported to occur on groundnut. About a dozen of them are quite destructive and reduce the yield considerably. *Aproaerema modicella* Deventer, *Amasacta albistriga* Walker, *Spodoptera litura* (F.), *Heliothis armigera* Huber, *Apis craccivora* Koch, *Frankliniella schultzei* (Tryban), *Scirtothrips dorsalis* Hood, *Thrips palmai* (Karny), *Empoasca kerri* Melicher, are considered as important destructive pests on groundnut (Amin and Mohammad, 1980).

2.1.1 Importance of *Spodoptera litura* (F.)

The *S.litura* is found throughout the tropical and subtropical parts of the world. It is widespread in India and polyphagous. The damage is done by larvae, which feed gregariously on leaves and fresh growth causing extensive damage.

In groundnut, even a slight damage to tips by *S.litura* reduces the yield by 4-10 per cent and medium or heavy cuttings of leaves reduces the yield by 13-37 per cent (Teich, 1969). The loss because of *S.litura* varied from 13-71 per cent in the states of Karnataka and Andhra Pradesh (Amin, 1983).

When *S.litura* is at very low level of infestation causes 6.98 per cent decrease in yield of groundnut genotypes Dh 8 and Dh 3-30 (Panchabhavi and Nethradhani Raj, 1987). And when this pest is at low, medium and high level

the yield loss was 19.6, 23.09 and 27.14 per cent, respectively compared to protected condition. The presence of 3 egg masses of an average size (each containing approximately 250 eggs) in 15 meter square area may cause significant loss of pod and haulm of groundnut (Panchabhavi and Nethradhani Raj, 1987). In transitional tracts of Karnataka (Dharwad), *S.litura* is known to cause yield loss upto the extent of 66.6 per cent (Kulkarni, 1989).

Density of the insect also influences the extent of yield loss. Dhir *et al.* (1992) reported that, one larva per groundnut plant at the seedling stage and flowering stage would cause a significant yield loss and at seedling stage, one larva per plant consumed about 54.7 per cent leaf area and reduced pod yield by 25.8 per cent. At flowering stage, one larva per plant consumed about 38.8 per cent leaf area and resulted in yield loss of 5.7 per cent. Another study by Singh and Sachan (1992) indicated greater yield loss when the pest infestation was at vegetative and bloom stages of the crop growth and the yield loss was between 23.0-31.4 per cent.

2.1.2 Importance of thrips

Thrips injury to peanut was first identified in 1919 by Watson (1922). There are number of species recorded world wide, but in South India, *Frankliniella schultzei* (Tryband) *Scirtothrips dorsalis* (Hood) and *Thrips palmi* (Karny) are important as they cause leaf injuries & stunting of plant in severe cases besides acting as vectors for viral diseases (PBND), which damage the crop severely.

Since the thrips can injure groundnut foliage in the seedling stage, most researchers did not recognise thrips as economic pest for decades. But recently because of vector activity to virus disease, it has attained the status of key pest in groundnut. But till now, there is no clear study to estimate yield loss due to thrips. However, Shivasubramanian and Palaniswamy (1986), estimated the yield loss to be 19.62 to 48.5 per cent due to thrips and leaf hoppers. The yield loss in groundnut due to thrips and leaf hoppers when occurred together was 23 per cent (Kennedy *et al.*, 1992).

2.2 Role of Integrated Pest Management

World wide insect damage to food crops costs farmers and consumers millions of dollars each year. Many insect control strategies have been employed. It is increasingly being realized that a reliance upon a single control strategy is not advisable. Heavy reliance upon insecticides has created a host of problems such as resurgence of pest populations, emergence of secondary pest outbreaks as a consequence of elimination of beneficial insect species, increased cost of food production and serious environmental pollution. Because most insect pests have high reproductive rates, they can eventually adopt to natural and synthetic pesticides, making complete eradication highly unlikely. Control measures therefore must aim at containment of insect populations rather than their eradication. This thinking led to the development of integrated pest management (IPM). IPM aims at keeping pest population below economic threshold level (ETL) through an

ecologically sound, economically practicable, socially acceptable and environmentally sustainable technology. Host plant resistance along with natural biological and cultural control measures is the basic component of an IPM system.

2.2.1 Host plant resistance

Host plant resistance is a phenomenon that has evolved in most higher plants to permit them to coexist with or to avoid many species of potential herbivore that could exploit them as food. Viewed broadly, it can take several forms that are usually connected with the feeding activity of the free living forms of the herbivore or the provision of food and shelter for their living.

It becomes essential to know the conceptual meaning of various mechanisms of resistance to insects before we attempt an analysis of the nature and magnitude of resistance to specific insects. The Table 1 lists and describes the different mechanisms of resistance to insects as elucidated by Painter (1951) and Weightman and Ranga Rao (1994).

The genus *Arachis* displays several of these resistance factors. Therefore, host plant resistance represents the key for opening up major advances in insect pest management because the use of resistance would have a major impact on the need or rather the lack of need for other control options.

Table 1 : Mechanisms of resistance

1. Antixenosis/ non-preference	:	Repellence of herbivore before they come in contact with the plant (Kairomones/Physical characteristics)
2. Antibiosis	:	Plant chemicals, when tasted/ingested by a herbivore, prove to be antimetabolite or toxins.
i. Latent Antibiosis	:	Antibiosis awaits being switched on by a challenge from a herbivore or by a systemic (within plants or pheromonal between plants) message.
ii. Temporary Antibiosis	:	Antibiosis is present only during a particular stage in the development of a plant
iii. Permanent Antibiosis	:	Antibiosis is a characteristic of a given plant species or organ.
3. Tolerance	:	Plant continue to develop and reproduce despite being attacked by herbivores.
4. Physical (Structural)	:	Plant structure (Trichomes, Thorns) or surface characteristics (Waxy cuticle etc) interfere in herbivores ability to exploit it.
5. Avoidance (Seasonal)	:	Plant life cycle does not coincide with the time, when key herbivores are active.
6. Avoidance (Spatial)	:	Plant evolves its forms that grow outside the big geographic or climatic range of a key herbivore.

2.2.2 Host plant resistance to *Spodoptera litura* (F.)

At present *S.litura* is a prominent defoliator associated with groundnut crop. So development of resistance to this in suitable varieties has been high priority for groundnut breeder.

One hundred groundnut cultivated genotypes were screened for resistance against foliage feeding insects (mainly *Spodoptera*, *Heliothis* and *Plusia* spp.) under natural infestation situation. The ICG No. 9106, 7165, 7449, 9094, 9039, 7128, 7067, 9012, 7050, 7031, 8081, 7093, 7147, 7737, 7852, 8994, 7912, 8978, 9084, 8997, 9065, and 7034 were less susceptible having a rating of three. While ICG No. 8873, 7554, 9189, 7410, 7884, 7406, 7520, 7875 receiving a rating of nine were considered as highly susceptible (Anon., 1984).

Fifty cultivated genotypes were screened for resistance to defoliators, viz., *Spodoptera*, *Heliothis* and *Plusia* spp. in all India co-ordinated research project on oil seed at Dharwad (Anon., 1985). Due to low infestation during *Kharif* 1985, majority of entries (40) fell under injury rating of 3. However, seven entries were under injury rating of 2. While three entries sustained higher damage with a rating of 4. At Hissar GC-79 and GC-333 were observed to be free from *S.litura* damage (Anon., 1985). Of the 50 cultivated groundnut genotypes screened for resistance to defoliator, twenty two entries fell below injury rating scale of 2, thirteen below rating 3, three below rating 4, six below rating 5 and one below rating 6 (Anon., 1986).

Fifteen *Arachis hypogaea* genotypes were screened in laboratory using choice tests for resistance to *Helicoverpa armigera* (3rd instar) and *S.litura* (1st, 3rd and 5th instars), only BG2 a virginia bunch variety was resistant to both pests (Singh *et al.*, 1993). Based on oviposition and feeding performance test conducted with the seven cultivars, NC Ac 2243 was least preferred, while the UPL Pn2 was the most preferred and EG Pn13 occupied an intermediate position (Xie Jia Li, 1987). The cultivar C-501 was most resistant and M-145 was the most susceptible to *S.litura* among nine groundnut varieties tested in laboratory, on the basis of growth and development of *S.litura* (Tiwari *et al.*, 1989).

Preliminary screening to assess the resistance to *S.litura* was carried out in field on 6 virginia bunch and 18 virginia runner accessions, and the highest resistance was recorded by virginia runner varieties, NC Ac 17840 NFG 79 and EC 21989 (Rajgopal *et al.*, 1988). In a screening by Patil *et al.* (1991) entries ICGV 87264 and 86598 have recorded the least damage (<17.5%) and entries ICGV. 86598 & 86125 have also recorded less damage (<27.5%) while other entries screened ICGV 86350, 86276, & 87287 have showed promise for resistance with the least damage (17.5%) at two stages of screening (75 and 90 DAS). RG 97 was another promising line resistant to *S.litura*.

Bioassay carried out with larvae as preliminaries to detect the mechanism of resistance (independent tests by Ranga Rao and Padgham) (Cf. Wightman and Ranga Rao, 1994) revealed no antibiosis effect on II-VI instar larvae when fed mature leaves of ICGV 86031. The main mechanism of resistance is currently thought to be tolerance, manifested as the enhanced ability of vegetative tissue to regrow following defoliation.

Padgham (Cf. Wightman and Ranga Rao, 1994) also found that newly hatched larvae had a marked propensity to vacate the leaves of this variety in the first two hours of free life. This suggests the resistance factor that influences the neonates is associated with the leaf surface, because their feeding activity is restricted to the scraping of the leaf surface. The antixenosis demonstrated by ICGV 86031 is likely to increase the first instar mortality that is characteristic of r-strategist noctuids (Kyi, *et al.*, 1991). When the crude extracts of resistant/ tolerant cultivars was sprayed on the susceptible cultivar JL 24 significant reduction in larval population was noticed (2.84 larvae/m) which was on par with the chemical control. The effects of extracts of resistant cultivars on larval survivability and reduction in egg laying (3.1 masses per 5 pairs) was noticed in plot studies. Which indicates the possible role of antibiosis (Gopali *et al.*, 1996). Therefore leaf extracts of resistant/ tolerant genotypes (including wild spp) could be made use in the management of groundnut pest which would be economical, eco-friendly and harmless to beneficial fauna.

Stevenson *et al.* (1993) studied resistance in different wild species of *Arachis*. They identified *A.kemph-mercadoi*, *A.appresipila*, *A.paraguariensis*, *A.stenophylla* and *A.villosa* as resistant to *S.litura*.

2.2.2.1 Biology and development of *Spodoptera litura* (F.) on different groundnut genotypes

Spodoptera litura is a polyphagous pest attacking 112 species of plants belonging to 44 families (Moussa *et al.*, 1960). Therefore vast number of

reports are available on the biology of this insect on different host plants. However, literature pertaining to biology and development of *S.litura* on groundnut is presented below.

The biology of *S.litura* was studied on different groundnut genotypes along with a wild tetraploid *A.monticola* (Patil *et al.*, 1995). The percent survival was least on the wild species, whereas it was maximum on Dh-3-30. The survivability on ICGV 86031, 87264, was comparatively less followed by ICGV 87165, 86350, 86699 and GBFDS 272. The larval duration was less on susceptible genotypes indicating higher rate of multiplication, while it was more in resistant genotypes. In a laboratory feeding bioassay (Todd *et al.*, 1991), it was found that the larval weights of fall army worm at 10 days of development ranged from 75.7 mg (Southern runner) to 26.5 mg (Florunner) indicating a wide diversity of growth responses on various peanut genotypes. But percent survival was very high on all the genotypes tested. Treatments with larvae at the smaller end of the range also exhibited an increased number of days required to develop to the pupal stage. Larvae fed with Florunner (resistant) required an average 3.7 more days to develop, compared with larvae fed with curly leaf. Less difference was noticed in pupal weights.

Leuck and Skimmer (1971) reported that the mean length of the life cycle of *S.frugiperda* was shorter (29 days) for the susceptible starr than for South eastern Runner (33.3 days). The mean percentage of moths was significantly less from larvae fed on foliage of the resistant cultivar, South eastern runner and also the mortality of the total insects fed with the

foliages was higher at all the stages of larval development and pupation on south eastern runner than Starr.

Longer larval duration, lower female fecundity and egg hatchability were also observed on NC Ac 2243 (Xie Jia Li, 1987). The duration of the generation was short and the intrinsic rate of increase was higher on the varieties of dwarf mutants and pol 2 than on any other cultivar (Tiwari *et al.*, 1981). But the pupal weights of male *S. frugiperda* tend to be greater than female on florunner groundnuts. On the same cultivar, leaf consumption was significantly greater on 40 day old plants than on 60 day old plants. Consumption decline significantly as the age of the leaves increased, and larval mortality rates were higher on older leaves. Larvae preferred to feed on younger leaves (Garner and Lynch, 1981). Several wild species of *Arachis* disrupted larval development and increased mortality in *S. frugiperda* (Lynch *et al.*, 1981). Whilst the majority of *A. hypogaea* cultivars were susceptible to *S. litura*, studies to identify resistance to this pest in cultivated groundnuts have shown that some cultivated genotypes of *A. hypogaea* possess low levels of resistance (Wightman *et al.*, 1990) but Stevenson *et al.* (1993) and Lynch *et al.* (1981) have indicated that many wild species of *Arachis* were highly resistant to attack by larvae of *S. litura*.

The mortality of neonate larvae on TMV 2 was significantly lower than that on any of other species of *Arachis*. Overall, the mortality and development of larvae recorded in the field were similar to those recorded for larvae on excised leaves of the same species in laboratory. When neonate larvae were exposed to excised leaves of *A. batizogaea*, *A. kemphmercadoi*,

A. appresila, *A. paraguariensis*, *A. stenophylla* and *A. villosa* mortality was greater than 94 per cent compared to less than 20 per cent on TMV 2. When third instar larvae were fed with pulped leaves they gained more weight than when exposed to intact leaves, except in the case of *A. chacoensis* and *Arachis* spp. 3007. Diets containing the chemical extracts of dried leaves of *A. kemphmercadoi*, *A. paraguariensis*, *A. appresiplla*, *A. chacoensis*, *A. glabrata* and *A. pseudovillosa* resulted in low larval weight gain (Stevenson *et al.*, 1993). Differences in the rate of development of larvae on *Arachis* species were readily apparent. At 5 days, larvae on all species had entered 2nd instar with the exception of larvae on *A. burkartii* which was still in the 1st instar. Larval growth on *A. monticola* was significantly faster than on *A. cordensaii*, *A. chacoense*, *A. correntina*, *A. lignosa*, *A. villosulicarpa* and *A. villosa*. By 10 days onwards differences in larval growth rates were even more pronounced. Larval survival to pupation also tends to be related to the rate of larval development. Survival was greatest (90%) on *A. monticola*, but only few (15-20%) larvae were able to complete larval development on *A. villosulicarpa*, *A. cardensii*, *A. lignosa* and *A. correntina*. None of the larvae completed their development on *A. burkartii*, *A. villosa*, and *A. repens*. They consumed the greatest amount of leaf tissue and required longest development period. Produced pupae weighed significantly lower than that of all the other wild species (Lynch *et al.*, 1981).

2.2.2.2 Mechanisms of Resistance

Each plant species has a unique set or collection of defence traits ranging from morphological to phytochemical parameters that have

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behavioural and physiological modifications for a potential herbivore consumer. The phytophagous insects must be able to locate the most suitable nutritional substrates among the multitude of plant species available within its temporal and spatial environment. Plants may alter the levels and balance of compounds that serve as insect feeding stimulants and deterrents which results in intimate associations becoming behaviourally/physiologically unacceptable.

2.2.2.2 a. Morphological and Anatomical features as Mechanism of Resistance

Structural and Morphological factors can serve as defence mechanisms for plants when herbivores come in contact with them. The most common contact factors that impart resistance are leaf toughness, cell-wall composition, proliferation of wounded tissues and pubescence etc.

Work on these aspects in groundnut is very meagre. The work is done on leaf toughness and pubescence. The variety C-501 fulfilled the nutritional requirement of *S. litura*, but was less suitable as a food plant, possibly on account of the texture of its leaves and/or the pubescence (Tiwari *et al.*, 1991). The same factor also influenced the life cycle of *S. litura* on genotype NC Ac 2243. (Xie Jia Li, 1987).

2.2.2.2 b. Biochemical basis of Resistance

It is known that biochemicals play an important role in the defence against insect herbivores as they act as insect repellents, feeding inhibitors,

and/or toxins, thus protecting plants at different phases of growth. But, adequate information on behavioural and physiological responses of insects to plant chemicals is needed. But, the chemicals responsible for insect resistance in crop plants have been identified only in a few instances and currently many scientists are investigating these factors.

Phenols : The term phenols includes a large group of organic aromatic compounds. They are known to provide resistance to the plants against insects. Four genotypes of groundnut and the susceptible control TMV 2 were evaluated for resistance to *S. litura*. All the genotypes contained 7 out of 8 phenolic acids detected. The highest total phenol content was found in the susceptible genotypes TMV 2 and M 13 (Singh and Sachan, 1992). The report of Rajgopal *et al.* (1988) revealed that there was no relationship between phenolics, nitrogen, potash and sodium contents with resistance accessions V 40, Ah 6429, NC Ac 17840, NFG 79 and EC 21989.

Polar phenolic compounds

The potential importance of quercetin-3-diglycosides and coffeoylquinic acid in the resistance of crop plants to attack by Lepidoptera is well established (Elliger *et al.*, 1981; Isman and Duffey, 1982; Duffey and Felton, 1991). Both rutin and chlorogenic acid severely inhibited larval development when presented to larvae at the same concentration as the equivalent compounds found in the foliage of *A. chacoensis*, *A. paraguariensis* and Hybrid (*A. chacoensis* x *A. hypogaea*) which suggests that these compounds

are at least responsible for the resistance to groundnuts to the larvae of *S.litura* (Stevenson, 1993).

Cuticular Lipids

Many herbivore insects seem to select their host plant on the basis of the chemical and ultra structural characteristics of the plant surface. Certain plant cuticular lipids can contribute to insect resistance by affecting insect feeding behaviour.

Fallarmy Worm that were fed a diet containing foliage of *A.ipaensis* from which the cuticular lipids had been extracted had increased larval weights and earlier pupation and adult emergence compared with individuals reared on diet with unextracted foliage. The developmental parameters of fallarmy worm that were fed on a diet containing the lipids that had been extracted from the foliage of *A.ipaensis* did not differ from those of insects fed on control diet. (Yang *et al.*, 1995).

2.3 Host plant resistance to thrips

Since thrips have attained a status of pest and vector in groundnut, resistant cultivar can help directly to control thrips damage and indirectly stop the vector activity of the thrips.

In an evaluation, genotypes ICGV-SM 85764, ICGV-SM- 85001 and ICGV-SM-83005 suffered low damage from sucking pests(Sithanathan *et al.*, 1991). The derivatives from GP-NC 343x NC 7 and GP-NC 343 x NC 17362 were resistant to thrips and jassids (Campbell *et al.*, 1987). Out of 872 entries

screened in Oklahoma, entries (introductions), 259594, 268779, 270804 and 306223, Virginia entry 290599 showed moderate resistance, whereas Starr the standard check entry ranked among the 10 least damaged entries (Young *et al.*, 1972). In another study by Kinzer *et al.*, (1972) plant introduction PI 280688 was promising for thrips resistance.

The resistance is also noticed in wild sp of *Arachis*, *A. batizocoi*, *A. chacoense*, *A. villosacarrentina*, *A. paraguariensis*, *A. pusilla*, and *A. repens* were resistant to thrips. The first generation hybrids between *A. hypogaea* and *A. villosa* or *A. batizocai* had very few thrips damaged leaves as compared to NC-6 (Stalker and Campbell, 1983).

Screening at ICRISAT has shown accessions ICGV 86031 (Dwivedi *et al.*, 1993), ICGV 86388 (Wightman and Ranga Rao, 1994), ICG 5040, ICG 5043 (Anon., 1986), ICG 2271 (Anon., 1984), NC Ac 2242, NC Ac 2214 (Anon., 1977), NC Ac 2240 (Anon., 1981), NC Ac 2232, NC Ac 2462, NC Ac 2575, NC Ac 2460 (Anon., 1980) as resistance/tolerance to thrips.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The information on material used and techniques adopted during the course of investigation are described here under. The study included four experiments.

Experiment No. 1

It was designed to screen the mutants for resistance to *Spodoptera litura* (F.).

Experiment No. 1a

It was designed to evaluate the selected genotypes against *Spodoptera litura*.

Experiment No. 2

It was designed to screen the mutants for resistance to thrips.

Experiment No. 2a

It was designed to evaluate selected genotypes against thrips.

Experiment No. 3

It was designed to evaluate development and life history parameters of *Spodoptera litura* (F.) on selected genotypes.

Experiment No. 4

It was designed to study the histological and biochemical basis of resistance to *Spodoptera litura* (F.) in selected genotypes.

3.1. Experimental material

Experiment 1

The material consisted of stabilized mutants isolated from earlier mutation breeding programme.

Artificial mutagenesis of Dharwad Early Runner (DER), a stable genotype, with 0.5 per cent Ethyl Methane Sulphonate (EMS) in our laboratory yielded foliar disease resistant, early maturing, and erect bunch valencia mutants, (viz., 1, 2, 8, 26, 39, 59 & 85). On subsequent mutagenesis with EMS, mutant (VL 1) yielded 22 secondary mutants (Sheshigiri, 1994). Since the mutants appeared to be resistant to *S.litura*. They were selected for systematic screening for resistance to *S.litura* along with original parents VL 1 & DER and resistant (GBFDS 272) and susceptible (JL 24) check in replicated trial during *Kharif* 1996 under unprotected condition. The characteristic features of these mutants and their parents are presented in Table 2 indicating substantial diversity for various characteristics.

Experiment 1a

The mutants 28-2, 45 and 110 resistant to *S.litura*, which have good productivity attributes were evaluated systematically in large scale along with parents (DER and VL 1), released varieties (ICGV 86590, TMV 2, Dh 40), resistant check (GBFDS 272) and susceptible check (JL 24) against *S.litura*

Table 2 : Characteristic features of mutants and parents

Genotype	Phenological characters				Pod features				Field disease score				
	NPB	NSB	Insl. type/a	Growth habit/b	Size/c	Break/d	Constriction/e	Reticulation/f	Kernel colour/g	No. of seeds/pod	Infection type/h	Late leaf spot	Rust
Parents													
1) DER	4	0	2	1	5	2	4	2	1	2-1-3	5	9.0	7.0
2) VL ₁ -1	2-4	0	2	5	1	1	1	1	2	3-2-1	5	8.5	2.0
Mutants													
3) 1-1	4	0	2	5	1	1	1	1	2	3-2-1	4	8.0	2.0
4) 2-1	4	0	2	5	2	2	2	1	2	2-3-1	5	9.0	2.5
5) 2-2	4	0-2	2	5	1	2	2	2	2	2-3-1	4	8.5	4.0
6) 3-1	4-5	3	2	5	5	1	1	2	3	2-1-3	3	7.0	2.0
7) 27-1	8	2-4	2	5	1	1	1	1	2	2-1-3	3	8.0	5.0
8) 28-1	5-6	2-4	1	4	2	1	3	1	2	2-1-3	4	5.0	3.5
9) 28-2	5-6	4-5	1	4	2	1	3	1	2	2-1-3	4	5.0	2.0
10) 29-1	4	0	1	5	3	2	3	3	2	2-1-3	3	8.5	2.5
11) 45	6	3-5	2	5	2	1	3	1	2	2-1-3	4	5.0	4.0
12) 78-1	4	0	2	5	1	1	1	1	2	3-2-1	3	8.0	3.5
13) 78-2	4	0	2	5	2	1	1	2	2	3-2-1	4	8.0	3.5
14) 98	5	4-5	2	5	2	1	3	2	2	2-3-1	3	5.0	5.0
15) 109-1	6	0	2	3	2	1	2	2	2	2-3-1	4	8.0	4.5
16) 110	5	3-4	1	4	2	1	3	1	2	2-1-3	3	5.0	8.0
17) 121	5	2-4	1	5	5	1	1	2	3	2-1-3	3	7.0	2.0
18) 139-1	4	0	2	5	1	1	1	1	2	3-2-1	5	9.0	3.5
19) 161	3-4	0	2	5	2	2	3	4	2	2-1-3	5	8.5	2.5
20) 171	4	0	2	5	2	1	1	3	4	3-2-1	4	8.0	2.5
21) 110(8)	4	4	2	5	3	1	2	1	2	3-2-1	5	8.0	7.0
22) 67-2	4	5	2	2	3	2	3	1	2	2-1	3	6.0	7.0
23) 104-9	4	4	2	5	3	3	3	1	2	2-1	3	6.0	7.0
24) VB type	4	-	2	5	4	1	1	1	2	2	3	7.0	5.0

a. Inflorescence type : 1. Compound; 2. Simple

b. Growth habit : 1. Procumbent-1; 2. Decumbent-1; 3. Decumbent-2; 4. Decumbent-3; 5. Erect.

c. Pod size : 1. Very big; 2. Big; 3. Medium; 4. Small; 5. Very small.

d. Pod beak : 1. Absent; 2. Slight; 3. Moderate; 4. Prominent

e. Pod constriction : 1. Absent; 2. Slight; 3. Moderate; 4. Prominent

f. Pod reticulation : 1. Absent; 2. Slight; 3. Moderate; 4. Prominent

g. Kernel colour : 1. Light tan; 2. Dark tan; 3. Purple; 4. Red.

h. Infection type : 1. Immune; 2. Resistant; 3. Moderately resistant; 4. Moderately susceptible; 5. Susceptible.

under high pest load condition during *Kharif* 1996 to assess the productivity potential. The experiment was replicated twice under un protected condition.

Experiment 2

The experimental material comprised of the same set of experimental material used in *Kharif* 1996 (Experiment 1) and evaluated against thrips during summer 1997. The experiment was replicated twice under unprotected condition.

Experiment 2a

Materials of Experimental No. 1a, were used here in replicated trial under unprotected condition during summer 1997.

Experiment 3

Three mutants (28-2, 45, & 110), along with parents VL 1 and DER and resistant (GBFDS 272) and susceptible (JL 24) checks comprised the experimental material.

Experiment 4

The same set of experimental material used in experiment 3, were made use of in this experiment.

3.2 Site of Experimentation

The field experiments (Experiment 1 & 1a, 2 & 2a) were conducted in Botanical Garden of University of Agricultural Sciences, Dharwad during *Kharif* 1996 and Summer 1997, respectively. The experimental material was raised in Randomized block design with two replications under unprotected conditions. The seeds were hand dibbled with spacing of 30cm x 10cm. The soil type was medium black (vertisol) with pH range of 7.0-7.5.

The remaining Experiment 3 and 4 were conducted in genetics and plant breeding division laboratory. Experiment 3 was conducted during *Kharif* 1996, when crop was 60 days old whereas Experiment 4 was conducted during Summer 1997, when the crop was 70 days old.

3.3. Climatic conditions

The main research station, University of Agricultural Sciences, Dharwad, is located on the transitional belt of Karnataka State at 15°31' north latitude, 75°07' east longitude and at an altitude of 678m above mean sea level.

The weekly mean meteorological data obtained from meteorological observatory attached to the Agricultural College Farm, Dharwad with regard to temperature humidity, rainfall and number of rainy days during course of investigation is presented in the Table 3 and 4 (Fig.1). The weather conditions of *Kharif* 1996 was characterized by average rainfall (545.6 mm), moderate number of rainy days (38), more wet period during 28-36 standard weeks due to continuous rainfall, 18.84-30.27°C of temperature and high humidity. Outbreaks of *S.litura* during pod development and filling stage (55-65 DAS or 32-33 week) provided excellent scope for meaningful screening of the material.

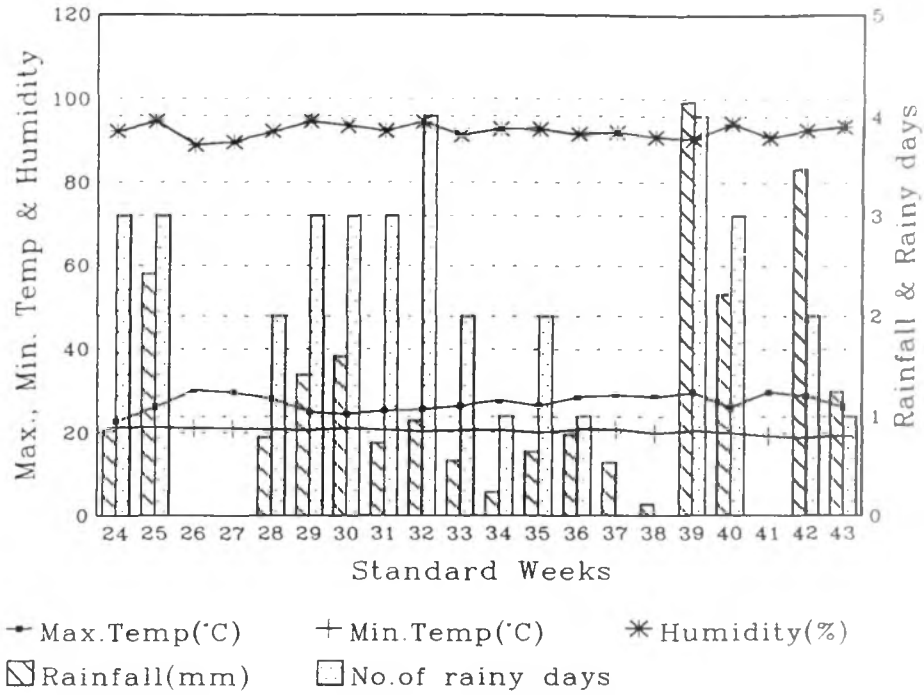
However, as evident from the data, summer season 1997 was characterized by moderate rainfall (179.9 mm), moderately high temperature (>20-36°C), moderately high humidity, less number of rainy days (9) and more rains were received during later part of cropping season (17-19 week).

Table 3 : Weekly meteorological data of Main Research Station, University of Agricultural Sciences, Dharwad during rainy season 1996.

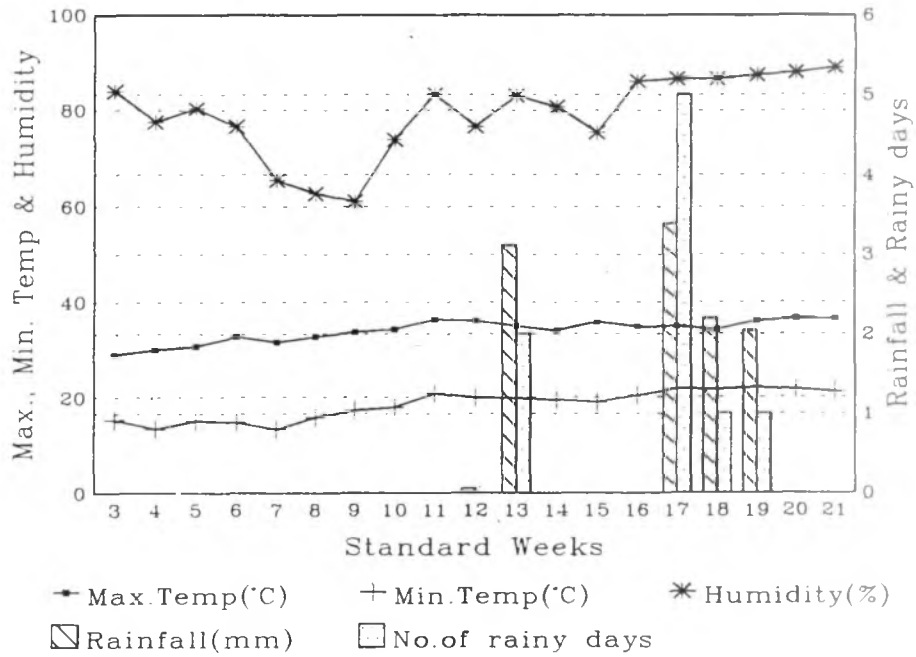
Standard weeks	Temperature (°C)		Humidity (%)	Rainfall (mm)	No. of rainy days
	Max.	Min.			
24 (June 10-16)	22.69	21.27	92.3	20.5	3
25 17-23	26.26	21.31	94.7	58.0	3
26 24-30	30.27	21.11	89.0	0.0	0
27 (July 1-7)	29.74	21.00	89.7	0.0	0
28 8-14	28.24	20.77	92.3	18.9	2
29 15-21	24.99	20.63	94.7	33.9	3
30 22-28	24.60	21.10	93.7	38.3	3
31 (July 29-Aug.4)	25.33	20.69	92.4	17.6	3
32 Aug. 5-11	25.63	20.30	94.6	23.0	4
33 12-18	26.57	20.61	91.4	13.3	2
34 19-25	27.80	20.63	92.9	5.7	1
35 (Aug.26-Sept.1)	26.59	20.11	92.7	15.5	2
36 Sept. 2-8	28.59	20.80	91.7	19.6	1
37 9-15	29.13	20.83	92.1	12.8	0
38 16-22	28.69	19.90	91.0	2.8	0
39 23-29	29.76	20.43	90.4	99.3	4
40 (Sept.30-Oct.6)	26.16	19.91	94.3	53.2	3
41 Oct. 7-13	29.86	19.17	91.0	0.0	0
42 14-20	28.90	18.84	92.7	83.3	2
43 21-27	26.24	19.29	93.6	29.9	1
TOTAL				545.6	38.00

Table 4 : Weekly meteorological data of Main Research Station, University of Agricultural Sciences, Dharwad during summer season 1997.

Standard weeks	Temperature (°C)		Humidity (%)	Rainfall (mm)	No. of rainy days
	Max.	Min.			
3 (Jan.15-21)	28.9	15.2	84.0	0.0	0
4 22-28	30.0	13.4	77.6	0.0	0
5 (Jan.29-Feb.4)	30.7	15.1	80.4	0.0	0
6 5-11	32.7	14.8	76.6	0.0	0
7 12-18	31.5	13.3	65.4	0.0	0
8 19-25	32.7	15.8	62.7	0.0	0
9 (Feb.26-Mar.4)	33.7	17.3	61.1	0.0	0
10 5-11	34.3	17.9	73.9	0.0	0
11 12-18	36.4	20.8	83.4	0.0	0
12 19-25	36.1	19.9	76.6	1.0	0
13 (Mar.26-Apr.1)	35.0	19.8	83.1	51.9	2
14 2-8	34.0	19.4	80.7	0.0	0
15 9-15	35.9	19.0	75.4	0.0	0
16 16-22	34.8	20.4	86.1	0.0	0
17 23-29	34.9	21.8	86.6	56.4	5
18 (Apr.30-May 6)	34.2	21.7	86.6	36.6	1
19 7-13	36.1	22.1	87.4	34.0	1
20 14-20	36.6	21.7	88.0	0.0	0
21 21-27	36.5	21.2	89.1	0.0	0
TOTAL				179.9	9



Kharif, 1996



Summer, 1997

Fig. 1: Weekly meteorological data of Main Research Station, U.A.S., Dharwad.

3.4 Cultivation Practice

The seed bed was prepared to fine tilth before taking up sowing. The recommended package of practice for groundnut cultivation in *Kharif* and Summer was adopted.

3.5. Methodologies adopted

Experiment 1 : Screening mutants against *S.litura*

Artificial infestation of *S.litura*

Spodoptera litura egg masses were collected from the unsprayed, commercial, neighbouring fields, uniform egg masses were selected and pinned on to the leaves at every 5 rows of 5m length plot in unprotected plot when the crop was 55 days old.

Experiment 1a : Evaluation of selected genotypes against *S.litura*

Artificial infestation of *S.litura*

The procedure was same as above except that an egg masses were pinned at every 3 rows of 2.5m length in unprotected plot, on 55 days old crop.

Experiment 3 : Development and life history parameters of *S.litura*

Artificial rearing of *S.litura*

The experimental material was raised in the field. All the cultivation practices, as recommended were adopted, except spraying of insecticides. Care was also taken to protect the plants from drifting of insecticidal sprays from neighbouring fields.

Egg masses of *S.litura* were collected from unsprayed commercial neighbouring groundnut fields. Uniform egg masses were selected and kept for hatching in disinfected rearing tin of diameter 6 inch and height 2.5 inch. The open top was covered by muslin cloth with rubber band. Third leaf from top to bottom was selected for rearing. The fresh leaves were provided daily after cleaning the tins. After pupation, pupae were kept in egg laying cages for moth emergence. Fresh groundnut plants wrapped with wet cotton were provided for egg laying.

Experiment 4 : Histological and biochemical basis for resistance

Sampling of material

Third leaf from top to bottom on main stem of healthy plants were collected randomly from 5 plants and pooled together.

Fixation

The plant samples collected were fixed in the standard fixative, F.A.A. (Formaline, Acetic acid, and 70% alcohol at the ratio of 1:1:18) prepared fresh. The samples were allowed to remain in the fixative for 24 hours.

Dehydration

Fixed material was thoroughly washed in 70% alcohol and further dehydrated by passing through 90% and absolute alcohol. Further dehydration was carried out using n-butanol in combination with ethanol. The material was treated for a fixed period of three hours in each of the grades. Details of the grades and the series are given below.

Ethanol : n-Butanol grades employed in the process of de- hydration

Sl.No.	Water content (%)	Ethanol (%)	n-butanol (%)
1	30	70	-
2	20	80	-
3	10	90	-
4	-	100	-
5	-	75	25
6	-	50	50
7	-	25	75
8	-	-	100

Paraffin infiltration

Paraffin wax (58-60°C melting point) was used for infiltration purpose. Small chips of paraffin wax were added successively to the medium of pure n-butanol containing dehydrated sample, until the medium reached a saturation point at room temperature. The specimen tubes were then kept in oven maintained 5°C above the melting point of the wax i.e., 65°C. Subsequent changes with fresh molten paraffin wax were given at every four hour intervals to replace even the last traces of butanol with paraffin.

Embedding

After the dehydration, the material free from n-butanol was embedded in wax by adopting paper-boat technique (Jensen, 1962). The paper boats of

appropriate size were prepared and smeared with glycerin. The material with molten wax was poured into the boats, immediately followed by preboiled molten wax. The material was arranged in paper boats in convenient manner for easy cutting of blocks.

Sectioning and affixing the sections

Uniform thin sections of 13 μ m thickness were cut by using ERMA rotary microtome. One per cent gelatin was used as an adhesive. A few drops of gelatin were put on the surface of a pre cleaned microslides, with the help of glass tube. The paraffin ribbons were cut into convenient lengths with the help of a blade and placed on the slides, flooded with adhesive solution. The slides were then warmed over a warming plate maintained at nearly 45°C to facilitate flattening and stretching of the ribbon. The excess adhesive was poured out and slides were later dried in a dust free environment for 72 hours under room temperature.

Staining for anatomical studies

For the anatomical observations the tissues were stained using the combination of Safranin and Fast green.

1. The paraffin embedded sections were deparffinised by passing the slides through xylene for 5 minutes. The sections were transferred to 1:1 mixture of xylene and absolute alcohol for another five minutes.
2. Sections were partially hydrated by passing through a series of alcohol of decreasing concentration i.e., absolute, 95%, 70% and 50% (5 min. in each).

3. The sections were stained with 1% Safranin in absolute alcohol for 2 hours.
4. Slides were washed thoroughly in water, passed quickly through acidified 70% alcohol to destain the excess colour and then passed rapidly through 95% and absolute alcohol.
5. Counter staining was done with Fast green (0.5% solution in 50% clove oil and 50% alcohol) for 1 to 5 minutes.
6. The Fast green was differentiated by placing in 50% clove oil, 25% alcohol, and 25% xylene.
7. The sections were placed in xylene, made three changes of at least 15 minutes each, and finally mounted with a coverslip using DPX mount.

Microscopic Observations and Measurements

The stained slides were observed under compound microscope at 10 x 40X magnification and the measurements were made with the help of ocular and stage micrometer.

Extraction of leaf material in alcohol

Leaf material was extracted in ethanol as per the procedure followed by Jayapal and Mahadevan (1968), and clarified with saturated solution of lead acetate. The excess lead acetate was precipitated by the addition of sufficient quantity of saturated solution of disodium hydrogen orthophosphate. The precipitate was re-separated by filtering the alcohol extract through Whatman No.1 filter paper and the filtrate was made upto a known volume of 80% alcohol.

Estimation of total Phenols

Estimation of total phenols present in plant samples was carried out by Folin ciocalteau method.

Reagents

1. Folin ciocalteau Reagent (1%).
2. Sodium Carbonate (2%).

Procedure

One ml of the plant extract was taken in a test tube to which 1 ml of Folin ciocateau Reagent followed by 2 ml of sodium carbonate solution was added. The tubes were shaken well and heated in a boiling water bath for exactly 1 minute and then cooled under running tap water. The blue solution was diluted to 25 ml with water and its absorbance was read at 650 nm in a spectrophotometer. The amount of phenol present in the sample was calculated from a standard curve prepared from catechol.

Estimation of Ortho dihydroxy phenol

Ortho-dihydroxy phenols (OD phenol) were estimated by using Arnow's method. Arnow's reagent specifically reacts with ortho-dihydroxy phenols to produce a pink coloured complex, the intensity of which can be measured by spectrophotometer.

Reagents

1. Arnow's Reagent : 10 gm of sodium nitrite and 10 gm of sodium molybdate was dissolved in distilled water and volume made upto 100 ml with distilled water and stored in brown bottle.

2. 0.05N HCl and 1N NaOH

Procedure

A suitable aliquot of alcohol extract was taken and 1 ml of 0.05N HCl and 1 ml of Arnow's reagent was added and mixed. Then 1 ml of 1N NaOH was added and mixed. Then the pink solution was made upto known volume with distilled water. The absorbance was read at 510 nm in a spectrometer. The amount of OD phenol in sample was calculated from standard graph prepared using catechol.

Estimation of total sugars

Total sugar in the plant sample was estimated by anthrone method (Dubois *et al.*, 1955).

Reagents

Anthrone Reagent : 2 gm of anthrone dissolved in one litre of concentrated H_2SO_4 .

Procedure

One ml of alcohol free aliquot was taken in a test tube and 4 ml of anthrone reagent was added dropwise slowly to each of the test tube kept in a ice bath. Then the test tubes were placed on a water bath for ten minutes and immediately kept in the ice bath. The absorbance was measured at 625 nm. The amount of total sugars were determined using the standard curve prepared from glucose.

Estimation of Tannins

Modified Folin Denis method was adopted to estimate tannins in the plant sample (Swain and Hillis, 1959).

Reagents

1. Folin-Denis reagent : 100 gm of $\text{Na}_2\text{WO}_4 \cdot 2\text{H}_2\text{O}$, 20 gm of phosphomolybdic acid and 50 ml of 85 percent H_3PO_4 were added to 750 ml of distilled water and refluxed for 2 hours. After cooling volume was made up to 1000 ml.
2. Saturated sodium carbonate solution kept over night and was seeded with $\text{Na}_2\text{CO}_3 \cdot 10 \text{H}_2\text{O}$ and filtered.

Procedure

One ml of the aliquot free from alcohol was taken in a test tube and 0.5 ml of Folin-Denis reagent was added. Exactly after 3 minutes, one ml of saturated sodium carbonate was added and volume was made up to 10 ml.

After one hour the absorbance was read at 725 nm. Using the standard curve prepared from catechol, tannin content was calculated.

3.6 List of Observations

Experiment 1 and 1a

1. Leaf area damaged due to *S.litura* (DS)
2. Number of leaves damaged due to *S.litura* (LDS)
3. Plant yield (gm)/plant (PY)
4. Shelling percentage in grams (SP)
5. Sound mature kernel percentage in grams (SMK %)
6. Test weight in grams (TW)
7. Yield (q)/ha (YH)
8. Plant population (PP)
9. Days to maturity (DM)
10. Per cent leaf area affected by late leaf spot (LLS) and rust (R)

Experiment 2 and 2a

1. Leaf damage/score due to Thrips (DT)
2. Number of thrips (NT)
3. Plant yield (gm) /plant (PY)
4. Shelling percentage in grams (SP)
5. Sound mature kernel percentage in grams (SMK %)
6. Test weight in grams (TW)

7. Yield (q)/ha (YH)
8. Plant population (PP)

Experiment 3

1. Larval count at 5, 10 and 15 days after hatching (DAH)
2. Larval weight (g/10 larvae) 5, 10 and 15 days after hatching (DAH)
3. Larval mortality at 5, 10 and 15 days after hatching (DAH)
4. Gain in weight (gms) by the larvae at 10 and 15 days after hatching (DAH)
5. Percentage of pupae
6. Mean larval period (MLP)
7. Per cent emergence of adults
8. Number of eggs/mass

Experiment 4

1. Thickness of total leaf
2. Thickness of epidermis along with cuticle (Adaxial and Abaxial)
3. Thickness of palisade parenchyma
4. Number of epidermal cells/mm (Adaxial and Abaxial)
5. Distance between phloem and epidermis
6. Total phenols (TP)
7. Ortho dihydroxy phenols (ODP)
8. Total sugars (TS)
9. Tannin content (TCC)

3.7 Description of Observation

1. Leaf area damaged due to *S.litura*

Five leaflets on the main stem from top to bottom were used for the estimation of leaf area damaged. Only top five leaflets were selected as the damage was confined to top young leaflets showing differences among entries. The area damaged was visually assessed. In each line five plants were separately estimated and average percentage damage was computed.

2. Leaves damaged due to *S.litura*

Top five leaflets on the main stem were selected and number of leaflets damaged was considered separately in five plants in each line and average leaflets damaged was computed.

3. Damage due to thrips

Top five leaflets on the main stem were selected. In each line 5 plants were selected. The damage was scored based on scale 0-2 (R), 2-4 (MR), 4-6 (MS), 6-8 (S) and 8-10 (HS) and average was computed.

4. Number of thrips

Unopened leaflets were taken and thrips were counted (both Adult and Nymphs). Five plants were selected randomly in a line and average was computed.

5. Per cent leaf area affected by late leaf spot and rust

The leaflets on main stem were scored for late leaf spot and rust based on scale given by Subrahmanyam and McDonald (1982).

6. Number of larvae

In each replication larval number was counted and average computed. The same is followed at 5, 10 and 15 days after hatching of eggs.

7. Mortality of larvae (%)

This was computed by assuming 350 eggs/mass as initial value and expressed in percentage.

8. Weight of larvae

Randomly 10 larvae were taken in each replication. They were weighed and average was computed. The same was followed at 5, 10 and 15 days after hatching of eggs.

9. Mean larval period

This was calculated by the formula

$$\text{Larval duration} = \frac{\sum \text{Individual pupa} \times \text{Number of days taken for pupation}}{\text{Total number of pupae}}$$

10. Per cent moth emergence

This was calculated using the formula

$$\text{Percent emergence} = \frac{\text{No. of adults emerged}}{\text{Total No. of pupae kept for adult emergence}} \times 100$$

11. Plant yield

Dry weight of pods of each line of five plants was separately weighed and average weight per plant was computed.

12. Yield per hectare

This was calculated by the formula

$$\text{Yield/ha} = \text{Yield/plant} \times \text{Number of plant/ha}$$

or

$$= \frac{\text{Plot yield} \times 10,000}{\text{Area of the plot (m)}}$$

13. Shelling percentage (SP)

100 gm of plant yield of a line was taken and shelling percentage was calculated by the following formula

$$\text{SP} = \frac{\text{Kernel weight}}{\text{Pod wt (100 gm)}} \times 100$$

14. Test Weight

Total number and weight of seeds (gm) were recorded from 100 gm of plant yield. Using this information 100 seed weight was calculated.

15. Sound Mature Kernel percentage (SMK%)

Well developed and shrivelled kernels were separated, counted and percentage was computed as

$$\text{SMK \%} = \frac{\text{No. of well developed kernels}}{\text{Total number of Kernels}} \times 100$$

16. Days to maturity

Number of days between sowing and harvesting of the crop was calculated.

3.8 Statistical Analysis

1. ANOVA

The data pertaining to all the characters were subjected for analysis of variance for Randomized Block Design (RBD) and the format of the model is given below.

Source of Variation	d.f	MSS	Cal F
Replication	(r-1)	RMSS	
Genotype	(g-1)	GMSS	GMSS
Error	(r-1)(g-1)	EMSS	RMSS
Total	rg-1		

Where,

r = Number of replication

\bar{g} = Number of genotypes

\bar{x} = Overall mean

$$S.E.D = \sqrt{\frac{2 \times EMSS}{r}} \times 100$$

$$CV = \frac{\sqrt{EMSS}}{\bar{x}} \times 100$$

$$CD = S.E.D \times t_{0.05} \text{ for } (r-1)(g-1) \text{ d.f}$$

$$S.Em = \sqrt{\frac{EMSS}{r}}$$

2. Phenotypic and genotypic variances

These were calculated according to the formula given by Lush (1940) and Choudhary and Prasad (1968).

$$\text{Genotypic variance} = \sigma^2 g = (\text{GMSS}-\text{EMSS})/r.$$

$$\text{Phenotypic variance} = \sigma^2 p = \sigma^2 g + \sigma^2 e$$

$$\text{Error variance} = \sigma^2 e = \text{EMSS}$$

3. Coefficient of variance

The components of variance, viz., phenotypic and genotypic variances were used for the estimation of phenotypic (PCV) and genotypic co-efficient of variation (GCV) as per the method suggested by Singh and Choudhary (1979).

$$\text{PCV} = \frac{\sqrt{\sigma^2 p}}{\bar{X}} \times 100$$

Where,

$\sigma^2 p$ = Phenotypic variance

\bar{X} = General mean of the characters

$$\text{GCV} = \frac{\sqrt{\sigma^2 g}}{\bar{X}} \times 100$$

Where, $\sigma^2 g$ = Genotypic variance

\bar{X} = General mean of the characters

4. Heritability

Heritability in broad sense (H) was computed as a ratio of genetic variance to the total variance (Hanson *et al.*, 1956).

$$H = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where, $\sigma^2 g$ and $\sigma^2 p$ are genotypic and phenotypic variances respectively.

5. Genetic advance (GA)

The extent of genetic advance to be expected was computed using the formula given by Robinson *et al.* (1949).

$$GA = H \times i \times \sigma p$$

Where,

H = Heritability

i = Selection differential at 5% selection intensity (2.06)

σp = Phenotypic standard deviation

6. Genetic advance percentage over mean (GAM)

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

Where,

GA = Genetic advance

\bar{X} = Mean of the character

7. Simple correlation

Simple correlation was estimated using the formula

$$r = \frac{\text{Cov. } xy}{(Vx \cdot Vy)^{1/2}}$$

Where,

Cov xy = Covariance between character x and y

Vx = Variance of character x

Vy = Variance of character y

r = Correlation coefficient

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results of the present investigation to search for cultivars with resistance/tolerance for *Spodoptera litura* and thrips with desirable agronomic attributes, are presented here under :

1. Screening mutants against *S.litura*.
2. Screening mutants against thrips.
3. Evaluation of selected genotypes against *S.litura*.
4. Evaluation of selected genotypes against thrips.
5. Biology of *S.litura* on selected genotypes.
6. Biochemical parameters in mutants.
7. Histological study in selected genotypes.

4.1 Screening mutants against *S.litura*

Twenty two mutants along with parents, resistant and susceptible checks were screened for resistance and productivity parameters viz., damage due to *S.litura* (DS), leaves damaged due to *S.litura* (LDS), plant yield (PY), test weight (TW), shelling percentage (SP) and sound mature kernel percentage (SMK %) under high pest load in natural field condition during *Kharif*, 1996.

4.1.1 Variation

Analysis of variance (Table 5a) revealed existence of significant variation among entries for all the characters except SMK.

Table 5 : Variance and components of variability for *Spodoptera* resistance and productivity in groundnut mutants.

a : ANOVA.

Source of variance	d.f.	Variables (MSS)					
		DS	LDS	PY	SP	TW	SMK
Replication	1	370.4	2.1	184.2	242.1	45.2	6.5
Genotypes	25	240.1**	0.8*	44.3**	63.3**	225.4**	17.9
Error	25	68.4	0.2	9.8	16.6	47.6	31.1

*, ** - Indicate the significance at 5% & 1% probability respectively.

b : Genetic components of variance.

Source of variance	Variables				
	DS	LDS	PY	SP	TW
PCV	35.2	20.4	35.5	8.4	24.1
GCV	26.2	14.4	28.3	6.4	19.4
H	55.6	50.0	63.6	58.3	65.1
GAM	40.3	21.1	46.5	10.0	32.4

To know the magnitude and nature of variation genotypic (GCV) and phenotypic coefficient variation (PCV), heritability in broad sense (H) and genetic advance over mean (GAM) were computed and are presented in Table 5b.

As revealed by PCV, variability was moderately high for DS (35.2%) and PY (35.5%), while it was low (8.4 to 24.1%) for other characters. A similar trend was evident when GCV was considered as a parameter. Heritability was high for all the characters with PY and TW recording more than 63.6 per cent and other characters between 50 to 58.3 per cent. GAM was moderately high for DS (40.2) and PY (46.5) due to high heritability and magnitude of variation. And it was moderate for TW (32.4), and low for LDS (21.1) and SP (10.0) on an account of low magnitude of variation.

4.1.2 Mean performance

The mean performance of the entries is presented in Table 6. The entries 28-2 (12.1), 45 (14.7) and 28-1 (18.5) recorded very less damage, which were significantly superior to resistant check GBFDS 272 (29.25). Among other mutants, 98-1 (28.4) and 110 (31) were on par to GBFDS 272. While parents VL 1 (40.45) and DER (46.9) were susceptible and comparable to JL 24 (40.65). The same mutants 28-1 (2.7), 28-2 (2.6) and 45 (2.35) also suffered less number of leaflet damaged due to *S.litura* as compared to GBFDS 272 (3.1) and JL 24 (4.3).

Among the mutants which suffered low DS and LDS, 45 (19.21) was on par with GBFDS 272 (18.82) for PY. While 28-1 (15.1) and 28-2 (9.1) showed low PY compared to GBFDS 272. But, 110 (23.63) was significantly superior to GBFDS 272. All these mutants were also superior to JL 24 (15.45).

Table 6 : Mean performance of mutants for resistance to *Spodoptera* and productivity.

Genotypes	DS	LDS	PY	SP	TW	SMK	LLS	R
1-1	38.90 e-h	4.07 e-h	17.98 a-e	74.77 a-c	48.63 d-g	89.21	8.0	2.0
2-1	40.65 g-j	3.82 d-h	9.27 f-h	79.86 a	38.61 gh	95.40	9.0	2.5
2-2	34.95 c-g	3.85 d-h	10.32 d-h	75.97 a-c	42.91 e-g	93.02	8.5	4.0
3-1	53.80 j	4.70 h	15.49 a-f	71.51 a-d	20.47 i	94.24	7.0	2.0
27-1	38.75 d-h	3.85 d-h	16.36 a-f	70.90 d-e	61.52 ab	86.87	8.0	5.0
28-1	18.55 ab	2.70 a-c	15.10 b-g	75.34 a-c	60.87 a-c	97.63	5.0	3.5
28-2	12.10 a	2.60 ab	9.10 f-h	74.55 a-c	55.97 a-e	97.62	5.0	2.0
29-1	53.85 j	4.35 f-h	17.48 a-f	71.90 a-d	44.40 e-g	86.49	8.5	2.5
45	14.70 a	2.35 a	19.21 a-c	71.88 a-d	55.13 a-f	95.75	5.0	4.0
78-1	36.20 c-g	4.15 e-h	19.08 a-c	76.25 a-c	41.89 fg	92.45	8.0	3.5
78-2	35.60 c-g	3.85 d-h	18.36 a-d	77.19 a-c	47.09 b-g	93.45	8.0	3.5
98-1	28.40 c	3.55 c-f	9.78 d-h	77.35 a-c	58.57 a-d	95.09	5.0	5.0
109-1	40.60 f-i	4.10 e-h	13.31 d-g	78.78 ab	50.22 b-g	90.89	8.0	4.5
110	31.00 c-f	3.80 d-g	23.63 a	71.53 a-d	55.79 a-f	94.11	5.0	8.0
121	46.05 h-j	4.20 e-h	15.94 a-f	76.33 a-c	42.16 e-g	96.22	7.0	2.0
139-1	36.70 c-g	4.05 e-h	6.99 gh	73.71 a-c	46.33 c-g	90.67	9.0	3.5
161	49.85 ij	4.50 gh	9.50 f-h	69.93 ce	41.57 fg	92.25	8.5	2.5
171	35.65 c-g	4.00 e-h	20.34 ab	73.95 a-c	45.28 d-g	92.71	8.0	2.5
110(8)	27.60 bc	3.40 b-e	14.50 b-g	74.44 a-c	55.84 a-f	97.90	8.0	8.0
67-2	44.50 g-j	4.05 e-h	14.62 b-g	65.28 de	45.09 d-g	89.73	6.0	7.0
104-9	49.90 ij	4.55 gh	19.01 a-c	71.38 b-d	66.56 a	97.17	6.0	7.0
VB type	29.35 c-e	3.40 b-g	11.39 c-h	76.58 a-c	42.42 e-g	91.07	8.0	3.0
VL 1	40.45 f-i	4.35 f-h	17.45 a-f	78.67 ab	52.20 a-g	93.88	8.5	2.0
DER	46.90 h-j	4.50 gh	3.49 h	61.72 de	25.28 hi	92.84	9.0	7.0
JL 24	40.65 g-j	4.30 f-h	15.45 a-f	79.22 ab	51.49 b-g	96.58	9.0	8.0
GBFDS 272	29.25 cd	3.10 a-d	18.82 a-c	73.91 a-c	61.45 ab	90.29	2.0	1.0
GM	36.72	3.85	14.66	75.26	48.37	93.60		
S.Em.±	3.42	0.23	2.23	2.88	4.88	3.94		
C.D. at 5%	9.64	0.89	6.47	8.41	14.21	NS		
CV (%)	18.64	12.40	21.44	5.43	14.26	5.97		

Value with same subscript do not differ at 5% level of significance.

The mutants 28-1 (75.34%) was significantly superior to GBFDS 272 (73.91%) for SP. Whereas 28-2 (74.55%) and 45 (71.88%) were comparable to GBFDS 272. The mutant 28-1 (60.81) was comparable to GBFDS 272 (61.45) for TW, whereas it was slightly lower in 28-2 (55.97) and 45 (55.13). All the resistant mutants were slightly heavier than JL 24 (51.49). The mutants 28-2 (97.62%) and 45 (95.75%) were superior to GBFDS 272 (90.29%) and were comparable to JL 24 (96.58%) for SMK.

Thus, the mutants 28-2 and 45 possess good pod and kernel features besides being resistant to *S.litura*. These mutants mature 10-15 days earlier than GBFDS 272 (115 days) and the yield was comparable to ruling bunch cultivar, JL 24.

4.2 Screening mutants against thrips

The entries screened for *S.litura* were also screened for resistance to thrips and productivity parameters, viz., damage due to thrips (DT), number of thrips (NT), plant yield (PY), test weight (TW), shelling percentage (SP) and sound mature kernel percentage (SMK %), under natural thrips incidence during summer 1997.

4.2.1 Variation

Analysis of variance revealed significant variation for all the characters except for SMK (Table 7a).

Genotypes exhibited moderate to high variability for DT (31.9), NT (33.9) and PY (35.3) as indicated by PCV. While it was low for TW (19.3%) and

Table 7 : Variance and components of variability for thrips resistance and productivity in groundnut mutants.

a : Anova.

Source of variance	d.f.	Variables (MSS)					
		DT	NT	PY	SP	TW	SMK
Replication	1	276.7	0.0	39.4	30.3	5.5	10.3
Genotypes	25	215.0**	16.5**	58.7**	121.6**	130.6**	53.0
Error	25	54.7	2.1	7.6	19.5	14.6	57.6

*, ** - Indicate the significance at 1% probability.

b : Genetic components of variance.

Source of variance	Variables				
	DT	NT	PY	SP	TW
PCV	31.9	33.9	35.3	14.5	19.3
GCV	24.5	29.8	30.9	12.4	17.3
H	59.4	77.1	76.9	72.2	79.8
GAM	39.0	61.4	55.9	21.7	31.9

SP (14.5%). The same pattern of variation was also exhibited on the basis of GCV. Moderate heritability was evident for DT (59.4%), while rest of the characters showed very high heritability(72.2%). GAM was high for NT (61.4%) and PY (55.9%) due to high magnitude of variation and heritability, whereas GAM was moderate (21.7 to 39.0%) rest of the characters on an account of low magnitude of variation (Table 7b).

4.2.2 Mean performance

Mean performance of entries is presented in Table 8. The mutants, VB type (15.6), 28-2 (19.2), 28-1 (21.3) and 45 (22.8) were significantly superior to GBFDS 272 (29.7) for DT. Among other mutants 110 (27.9) and 139-1 (30.4) were comparable to GBFDS 272. The same mutants 28-2 (3.1), 45 (5.3) and 28-1 (6.4) also showed low NT, which were significantly superior to resistant check GBFDS 272 (8.3). Among mutants which showed less DT and NT, 28-2 (20) and 45 (15.74) were significantly superior for PY when compared to GBFDS 272 (11.09), while the mutant 28-1 (12.19) was comparable to GBFDS 272. The resistant mutants 45 (65.73%) and 28-2 (64.05%) were significantly superior to GBFDS 272 (61.92%) and were on par to JL 24 (64.92%) for SP. The mutant 28-2 (54.08) was significantly superior to GBFDS 272 (51.42) for TW. While 45 (51.49) and 28-1 (51.17) were on par to GBFDS 272. TW of all these resistant mutants were significantly superior over JL 24 (43.03). With respect to SMK, the resistant mutants 45 (95.97%), 28-2 (94.45%) and 28-1 (93.32%) were superior to both resistant GBFDS 272 (87.09%) and susceptible check JL 24 (82.44%).

Table 8 : Mean performance of mutants for resistance to thrips and productivity.

Genotypes	DT	TN	PY	SP	TW	SMK
1-1	38.32 e-i	7.00 c-e	24.17 ab	61.69 b-e	47.37 b-f	87.52
2-1	31.40 a-f	8.20 c-e	19.18 b-f	56.77 c-h	35.84 h-j	80.07
2-2	47.30 h-j	8.80 d-f	14.08 f-l	52.55 f-i	38.56 g-i	82.49
3-1	47.00 g-j	9.40 e-h	10.64 j-m	51.62 g-i	30.10 jk	79.39
27-1	45.90 f-j	10.70 f-i	15.44 e-k	59.23 b-g	47.23 b-c	85.32
28-1	21.30 a-c	6.40 cd	12.19 h-l	50.07 h-j	51.17 a-d	93.32
28-2	19.20 ab	3.10 ab	20.00 b-e	64.05 a-d	54.03 ab	94.45
29-1	34.60 c-h	10.80 f-i	11.95 i-l	58.86 b-h	48.79 a-f	91.06
45	22.80 a-d	5.30 b-c	15.74 e-j	65.73 a-c	51.49 a-d	95.97
78-1	35.60 c-i	11.70 g-j	23.93 ab	58.45 b-h	52.76 a-c	93.10
78-2	33.90 b-g	8.20 c-e	13.05 g-l	63.28 a-d	50.11 a-e	88.50
98-1	37.00 d-i	10.60 f-i	18.19 c-g	60.33 d-g	49.93 a-e	92.92
109-1	50.40 ij	12.00 h-j	21.29 a-d	58.76 b-h	43.63 d-h	83.29
110	27.90 a-e	8.90 d-h	26.77 a	71.47 a	55.48 a	93.06
121	56.10 j	11.90 h-j	18.20 c-g	46.84 ij	38.30 g-i	89.49
139-1	30.40 a-e	8.60 d-f	10.70 j-m	56.99 b-h	42.43 e-h	80.39
161	40.00 e-i	11.00 f-i	11.20 j-m	65.89 ab	37.53 h-j	91.57
171	31.90 d-f	9.60 e-h	17.65 c-i	56.76 d-h	38.90 g-i	86.88
110(8)	31.30 a-f	8.80 d-f	17.92 c-g	58.26 b-h	41.56 f-i	89.60
67-2	42.50 e-j	9.70 e-h	10.00 k-m	42.30 jk	39.01 f-i	80.69
104-9	48.60 h-j 1	3.80 j	17.87 c-h	63.86 a-d	51.29 a-d	85.75
VB type	15.60 a	0.90 a	9.35 lm	54.11 e-i	33.95 ij	87.59
VL 1	34.70 c-h	9.30 d-h	23.32 a-c	56.52 d-h	45.85 c-g	87.14
DER	46.10 f-j	8.70 d-f	6.34 m	35.24 k	22.50 k	78.27
JL 24	46.70 g-j	13.30 i-j	23.09 a	64.49 a-d	43.03 e-h	82.44
GBFDS 272	29.70 a-e	8.30 d-f	11.09 j-m	61.92 b-e	51.42 a-d	87.09
GM	36.29	9.00	16.31	57.54	43.83	87.22
S.Em.±	5.23	1.02	1.95	3.12	2.70	5.37
C.D. at 5%	15.23	2.99	5.70	9.09	7.88	NS
CV (%)	20.83	16.96	16.96	7.67	8.70	8.70

Value with same subscript do not differ at 5% level of significance.

4.3 Evaluation of selected groundnut genotype against *Spodoptera litura* (F.)

The mutants (28-2, 45 and 110) resistant to *S.litura* and which have good attributes were evaluated in a large scale trial along with varieties released for cultivation (TMV 2, Dh-40, JL-24 and ICGV 86590), parents (DER and VL 1) and resistant check (GBFDS 272) for damage due to *S.litura* (DS), number of leaflets damaged due to *S.litura* (LDS), plant yield (PY), yield per hectare based on plot yield (YH), shelling percentage (SP) and test weight (TW) during *Kharif*, 1996.

4.3.1 Variance

As revealed by ANOVA, all the characters except leaves damaged due to *S.litura* showed significant variation (Table 9a). The components of variation viz., PCV, GCV, H and GAM indicated the heritable nature of this variation (Table 9b).

4.3.2 Mean performance

Mean performance of the genotypes is presented in Table 10.

The mutants 28-2 (10.0) and 45 (10.9) were significantly superior to released varieties, parents and GBFDS 272 (23.5 to 38.7) for damage due to *S.litura*. However, mutant 110 (22.10) was comparable to released varieties, parents and GBFDS 272.

The same mutants 28-2 (2.1) and 45 (2.4) were superior to cultivated varieties and parents (3.1 to 4.3) but on par with GBFDS 272 (2.0) for number

Table 9 : Variance and components of variability for *Spodoptera* resistance and productivity in selected groundnut genotypes.

a : ANOVA.

Source of variance	d.f.	Variables (MSS)					
		DS	LDS	PY	YH	SP	TW
Replication	1	2.7	0.3	0.3	13.8	0.2	0.0
Genotypes	9	190.2**	1.3	90.4**	283.5**	43.6**	335.6**
Error	9	30.4	0.6	15.0	58.6	1.9	5.4

** - Indicate the significance at 1% probability.

b : Genetic components of variance.

Source of variance	Variables					
	DS	LDS	PY	YH	SP	TW
PCV	44.1	29.5	28.7	28.7	6.4	24.7
GCV	37.5	18.1	23.3	23.3	6.1	24.3
H	72.4	37.6	65.6	65.6	91.3	96.8
GAM	65.7	22.9	38.9	38.9	12.1	49.3

Table 10 : Mean performance of selected genotypes for resistance to *Spodoptera* and productivity.

Genotypes	DS	LDS	PP	PY	YH	SP	TW	DM
28-2	10.0 a	2.1	141	22.58 b	45.38 a-c	73.25 b	65.15 ab	105
45	10.9 ab	2.4	129	19.89 b	36.02 c	72.60 b	60.60 bc	105
110	22.1 a-d	4.2	67	36.56 a	40.42 bc	75.25 b	62.10 bc	105
VL 1	23.1 b-e	3.7	92	22.42 b	44.32 a-c	69.95 cd	57.95 c	105
DER	30.6 d-f	4.3	138	8.69 c	18.36 d	66.25 e	24.95 g	105
TMV 2	28.6 d-f	3.4	166	22.76 b	52.97 a-c	79.40 a	42.10 f	105
Dh 40	35.3 ef	3.1	199	21.31 b	60.20 a	78.40 a	48.50 de	105
ICGV 86590	23.5 c-e	3.3	146	25.02 b	51.35 a-c	67.65 de	45.50 ef	105
GBFDS 272	15.3 a-c	2.0	193	20.30 b	55.38 ab	75.12 b	67.70 a	114
JL 24	38.7 f	3.9	161	21.74 b	49.78 a-c	79.15 a	52.95 d	105
GM	23.81	3.40		22.13	45.42	73.70	52.75	
S.Em.±	3.90	0.56		2.74	5.41	0.99	1.40	
CD at 5%	12.48	NS		8.78	17.32	3.17	4.48	
CV (%)	23.17	24.50		17.55	16.85	1.90	2.66	

Value with same subscript do not differ at 5% level of significance.

of leaves damaged due to *S.litura*. Plant yield of mutant 28-2 (22.58) and 45 (19.89) were comparable to released varieties, parents and GBFDS 272 (20.3 to 25.07). However, mutant 110 (36.56) recorded significantly high plant yield. While DER (8.69) recorded low plant yield compared to released varieties, parents and GBFDS 272.

Yield (q) per hectare of mutants 28-2 (45.38), 45 (36.02) and 110 (40.42) was comparable to released varieties (51.03 to 52.75), parent VL 1 (44.32) and GBFDS 272 (55.38), except for variety Dh 40 (60.2) which recorded significantly high yield per hectare as an account of high plat population (199). While DER (18.36) recorded lowest yield. Mutants recorded slightly lower shelling percentage but high test weight compared to released varieties.

4.4 Evaluation of groundnut genotypes against thrips

The genotypes evaluated against *S.litura* were also assessed for damage due to thrips (DT), number of thrips (NT), plant yield (PY), yield (q) per hectare (YH), shelling percentage (SP) and test weight (TW) during summer 1997.

4.4.1 Variance

Analysis of variance (Table 11a) indicated significant variation for all the characters except for yield per plant and this variation was of heritable nature as indicated by components of variation viz., PCV, GCV, H and GAM (Table 11b).

Table 11 : Variance and components of variability for thrips resistance and productivity in selected groundnut genotypes.

a : ANOVA.

Source of variance	d.f.	Variables (MSS)						
		DT	NT	PY	YH	SP	TW	SMK
Replication	1	0.7	0.8	4.6	28.4	7.5	19.6	1.9
Genotypes	9	128.1**	12.5**	9.2	26.3**	83.5**	171.3**	17.1
Error	9	5.4	1.7	7.2	11.1	10.3	12.0	17.7

** - Indicate the significance at 1% probability.

b : Genetic components of variance.

Source of variance	Variables					
	DT	NT	PY	YH	SP	TW
PCV	23.2	27.5	19.4	22.4	10.7	23.3
GCV	22.3	23.8	7.1	14.3	9.4	21.9
H	91.8	74.9	13.3	40.7	77.9	86.8
GAM	44.0	42.5	5.3	18.8	17.2	42.0

4.4.2 Mean performance

Mean performance of the genotypes for different characters is presented in Table 12.

The resistant mutants 28-2 (19.6) and 45 (27.5) recorded significantly less damage due to thrips compared to GBFDS 272 (34.9), parents (38.9) and released varieties (35.9 to 47.4). However, ICGV 86590 (28.0) was on par with mutants 28-2 and 45 for damage due to thrips. Number of thrips on 28-2 (4.9) and 45 (6.4) was significantly lower compared to all other genotypes (7.9 to 12). Plant yield of mutant 28-2 (15.08) and 45 (14.58) was comparable to released varieties (15.14 to 16.16) and superior to GBFDS 272 (10.42). Yield per hectare of the mutants 28-2, 45 and 110 (15.95 to 22.20) was comparable to released varieties, parents and GBFDS 272 (16.24 to 23.68). Shelling percentage of mutants 28-2 (65.92%) and 45 (64.38%) was slightly less compared to released variety TMV 2 (69.22%) and JL 24 (68.55%) but comparable to resistant of the released varieties, parents and GBFDS 272. However, mutant 110 (69.22%) was on par with TMV 2 and JL 24. With respect to test weight all the mutants 28-2, 45 and 110 (48.1 to 52.7) were superior to released cultivars, parents and GBFDS 272 (20.66 to 44.84).

Thus, mutants 28-2 and 45 were resistant to *S.litura* and thrips. The yield levels of these mutants were superior or comparable to released varieties besides having desirable attributes.

Table 12 : Mean performance of selected genotypes for resistance to thrips and productivity.

Genotypes	DT	NT	PP	PY	YH	SP	TW	SMK
28-2	19.6 a	4.9 a	62	15.08	20.50 ab	65.92 ab	49.80 b	86.21
45	27.5 b	6.4 a	44	14.58	15.95 bc	64.38 ab	48.10 bc	91.07
110	39.2 c	10.9 bc	75	13.35	22.20 ab	69.22 a	52.74 a	91.23
VL 1	38.9 c	9.5 abc	55	15.80	22.00 ab	60.45 b	39.03 d	82.41
DER	38.9 c	10.9 bc	40	13.78	12.36 c	49.72 c	20.66 e	88.64
TMV 2	35.9 c	12.1 bc	50	15.55	17.45 abc	71.13 a	33.25 d	87.08
Dh 40	47.4 d	11.7 bc	55	16.16	20.18 ab	68.79 a	37.38 d	90.03
ICGV 86590	28.0 b	10.8 bc	66	15.40	22.35 ab	61.10 b	40.21 d	85.61
GBFDS 272	34.9 c	7.9 ab	69	10.42	16.24 abc	58.99 b	44.84 bcd	84.13
JL 24	39.8 c	12.0 bc	70	15.14	23.68 a	68.55 a	41.03 cd	87.74
GM	35.11	9.71		14.87	19.29	63.83	40.70	87.41
S.Em.±	1.64	0.94		1.90	2.35	2.27	2.45	2.98
CD at 5%	5.86	3.02		NS	7.54	7.29	7.86	NS
CV (%)	6.62	13.79		18.13	17.28	5.04	8.54	4.81

Value with same subscript do not differ at 5% level of significance.

4.4.3 Association among pest and disease parameters

Selection is perhaps the most important activity in all the plant breeding programmes. Therefore, correlation technique aid in isolation of desirable types from the population by providing information on association of characters.

The correlation coefficients among pest (DS, LDS, DT and NT) and disease (LLS and R) resistance parameters were worked out as per the procedure described in material and methods and are presented in Table 13. Correlation study among pest and disease resistant parameters revealed a significant and positive association among pest resistant parameters. The characters, damaged due to *S.litura* and late leaf spot were positively and significantly associated, indicating the scope for indirect selection for these two characters.

4.5 Biology of *Spodoptera litura* (F.) on selected groundnut genotypes

Growth and development of an insect on different genotypes becomes an important criterion in investigating mechanism of resistance. Hence, *S.litura* was reared artificially on mutants (28-2, 45 and 110), along with parents (VL 1 and DER), resistant check (GBFDS 272) and susceptible check (JL 24). Based on growth and development of *S.litura* on different genotypes, parameters viz., Number of larvae, mortality of larvae, weight per 10 larvae, and weight gain by larvae at different intervals, number of pupae, per cent moth emergence, mean larval period and number of eggs per mass was computed.

Table 13 : Correlations among pest and disease resistance parameters in mutants.

	DT	NT	DS	LDS	LLS	R
DT	1.0000	0.8155**	-0.1367	0.7270**	0.2882	0.1791
NT		1.0000	0.5696**	0.6722**	0.2319	0.3064
DS			1.0000	-0.1626	0.3489	-0.0302
LDS				1.0000	0.5766**	0.0091
LLS					1.0000	0.1863
R						1.0000

** - Indicates significance at 1% probability.

4.5.1 Variance

The analysis of variance revealed significant variation for all the characters except number of pupae, mortality of larvae at 5th day, and emergence of moths (Table 14a).

As revealed by PCV (Table 14b), variation was high for number of larvae at 5th and 10th day, mortality at 5th day, weight of the larvae at 10th day, weight gain by larvae at 10th day, and number of eggs per mass (40.53 to 65.4%), variation was moderate for number of larvae at 15th day, mortality at 10th day, weight of the larvae at 5th and 15th day, and weight gain by larvae at 15th day (22.25 to 37.15%) and variation was low for mean larval period and mortality of larvae at 15th day (16.16 and 7.5%). The pattern of variation was unchanged when GCV was considered as a parameter. Heritability was high for number of larvae at 10th day, mortality of larvae at 10th day, weight of the larvae at 10th and 15th day, gain in weight at 10th day, and number of eggs per case (>51%). While it was moderate for rest of the parameters (34.68 to 47.88%). GAM was high for number of larvae at 5th and 10th day, mortality at 5th day, weight of the larvae at 10th day, gain in weight at 10th day and number of eggs per case (43.06 to 129.97%) as an account of higher heritability and magnitude of variation. Whereas GAM was moderate for number of larvae at 15th day, mortality of larvae at 10th day, weight of larvae at 5th and 15th day and weight gain by larvae at 15th day (28.81 to 36.03%). While GAM was low for mortality of larvae at 15th day and mean larval period (14.3 and 9.46%), due to low heritability and magnitude of variation.

Table 14 : Variance and components of variability for life history parameters of *Spodoptera litura* (F.).

a : ANOVA

Source of variance	Larval No.			Larval mortality (%)			Larval weight (mg)			Gain in weight(mg)			No. of pupae emergence (%)		No. of MLP eggs/ mass	MLP (days)
	5 DAH	10 DAH	15 DAH	5 DAH	10 DAH	15 DAH	5 DAH	10 DAH	15 DAH	10 DAH	15 DAH	(%)	(%)			
Replication	1212.34	540.14	1400.90	23.80	44.11	114.42	0.41	352.49	8411.62	420.61	8820.89	0.14	4.42	374.75	3.00	
Genotypes	12327.56*	9354.71*	2888.52*	1041.67	763.70*	235.80*	2.79*	974.34**	43391.46*	887.70**	32074.80*	86.93	65.27	99339.66**	4.93**	
Error	3558.88	2066.97	885.90	399.63	168.75	72.33	0.75	114.60	10525.23	98.00	10846.74	69.19	29.98	1196.64	0.88	

*, ** - Indicate the significance at 5% & 1% probability respectively.

b : Genetic components of variance.

Source of variance	Larval No.			Larval mortality (%)			Larval weight (mg)			Gain in weight(mg)			No. of MLP eggs/ mass		No. of MLP (days)
	5 DAH	10 DAH	15 DAH	5 DAH	10 DAH	15 DAH	5 DAH	10 DAH	15 DAH	10 DAH	15 DAH	(%)	(%)		
PCV	46.36	47.79	37.15	50.54	32.19	16.16	29.51	40.53	34.29	42.32	22.25	65.40	7.50		
GCV	31.13	35.13	24.35	29.84	23.50	10.59	20.36	34.26	24.49	36.06	35.42	64.23	5.90		
H	45.09	54.02	42.97	34.88	54.03	42.96	47.88	71.43	51.00	72.87	39.48	96.47	60.53		
GAM	43.06	53.19	32.88	52.62	35.59	14.30	29.02	59.68	36.03	63.54	28.81	129.97	9.46		

4.5.2 Mean performance

Mean performance of the genotypes is presented in Table 15.

The mutant 45 recorded significantly less number of larvae (59.33, 51.66 and 43.66) and higher percentage of larval mortality (84.04, 85.23 and 87.52%) at all the three intervals, compared to other genotypes. The mutant 28-2, 110 and resistant check GBFDS 272 recorded less number of larvae at 5th, 10th day after hatching (DAH) and higher percentage of larval mortality at first interval (10 DAH), compared to JL 24 whereas at 15th DAH there was no significant difference among these genotypes for number of larvae due to mortality of larvae at later stages. But mutant 45 recorded significantly less number of larvae at 15 DAH inspite of lack of mortality at later stages.

The mutant 28-2 recorded significantly less weight of larvae (2.33, 27.46 and 268.66) and gain in weight (25.13 and 241.2) at all the stages compared to other genotypes. The mutant 45 also recorded less weight of larvae at 5th and 10th DAH and gain in weight at first interval (10 DAH) compared to resistant check GBFDS 272. The mutant 110 and resistant check GBFDS 272 recorded less weight and gain in weight at all the stages of observations compared to JL 24 and parents.

There was no significant difference among the genotypes for percentage of pupae developed from larvae at 15 DAH and percentage of moth emergence from total pupae. The mutants 28-2 (21.54) and 45 (21.3) recorded significantly higher mean larval period compared to other genotypes. The same mutants 28-2 (170) and 45 (144.66) recorded less number of eggs per mass compared to all other genotypes. Whereas, the mutant 110 and parent VL 1

Table 15: Life history parameters of *Spodoptera litura* (F.) on selected genotypes.

Genotypes	Larval No.		Larval mortality (%)			Larval weight (mg)			Gain in weight(mg)			% pupae emergence (%)	Moth No. of eggs/mass	MIP (days)	
	5 DAH	10 DAH	15 DAH	5 DAH	10 DAH	15 DAH	5 DAH	10 DAH	15 DAH	10 DAH	15 DAH				
28-2	157.66ab	126.00ab	110.00b	54.95	63.99ab	68.56b	2.33a	27.46ab	268.66a	25.13b	241.20a	25.75	58.58	170.00a	21.54a
45	59.33a	51.66a	43.66a	84.04	85.23a	87.52a	3.40ab	24.50a	288.33ab	21.10a	263.83ab	27.97	57.91	144.66a	21.30a
110	172.33bc	116.00ab	97.33b	41.23	66.85ab	72.18b	4.10b	56.93bc	402.00ab	52.83cde	345.06abc	20.50	76.74	354.00b	19.50bcd
VL 1	155.66ab	154.66b	143.33b	55.52	55.80b	59.04b	4.16b	63.13cd	534.66ab	58.96de	471.53bc	16.84	76.99	334.00b	19.82bcd
DER	196.66bc	157.66bc	124.00b	43.80	54.94bc	64.56b	4.66b	72.06d	565.33ab	67.73e	493.26c	14.77	36.82	0.00	18.23d
GBFDS 272	202.00bc	138.00b	144.00b	42.28	60.56b	67.42b	4.33b	44.40bc	402.66ab	40.06bc	358.26abc	15.47	51.78	502.00d	18.38cd
JL 24	272.00c	238.00c	110.00b	22.28	31.99c	68.47b	5.36c	57.36cd	529.66ab	48.46cd	472.30c	17.11	57.91	456.00c	18.93bcd
G.M.	173.66	140.28	106.09	49.01	59.91	69.68	4.05	49.41	427.33	44.90	377.92	19.77	59.53	281.57	19.68
S.Em.±	33.44	26.24	17.18	11.54	7.49	4.91	0.50	6.18	59.23	5.71	60.12	5.37	12.29	19.97	0.43
C.D. at 5%	106.15	80.90	52.96	NS	23.11	15.13	1.54	19.05	182.56	17.61	185.29	NS	NS	61.55	1.34

Value with same subscript do not differ at 5% level of significance.

recorded less number of eggs per case compared GBFDS 272 and JL 24. However, there was no egg laying by moths emerged from larvae reared on DER, which needs reconfirmation.

The mutant 28-2 recorded less number of larvae at initial stages and less gain in weight at both intervals. Whereas, mutant 45 recorded less number of larvae at all the stages but less gain in weight only in first interval while mutant 110 was comparable to resistant check GBFDS 272 at all the stages for both number of larvae and gain in weight.

4.6 Biochemical parameters in mutants

Plants defend against herbivores by inherent biochemicals, hence genotypes screened against *S.litura* and thrips were assessed for total phenol (TP), orthodihydroxy phenols (ODP), total sugars (TS) and Tanins (TC).

4.6.1 Variance

Analysis of variance revealed significant variation for all the biochemical parameters under consideration (Table 16a).

Based on PCV, variability was high for total sugars, total phenols and O.D. phenol (41.4 to 66.19%) and moderate for tanin content (29.5%). There was no change in the trend of variation, when GCV was considered as a parameter. Heritability was high for all the characters (>64.11%). GAM was also high for all the characters (>58.7%) because of either high magnitude of variation or heritability (Table 16b).

Table 16 : Variance and components of variability for bio-chemical parameters in groundnut mutants.

a : ANOVA.

Source of variance	d.f	Variables (MSS)			
		TP	ODP	TC	TS
Replication	1	2.2	0.2	235.9	1084.0
Genotypes	25	56.1**	21.0**	1293.7**	31186.4**
Error	25	3.4	0.7	22.3	665.9

** - Indicate the significance at 1% probability.

b : Genetic components of variance.

Source of variance	Variables			
	TP	ODP	TC	TS
PCV	44.8	65.1	29.50	41.4
GCV	42.1	62.7	28.49	40.8
H	88.4	92.7	96.60	95.8
GAM	81.6	124.6	58.70	82.4

4.6.2 Mean performance

Among the resistant mutants to *S.litura* and thrips, 28-1 (6.45), 45 (5.2) and 28-2 (4.5) indicated significant superiority for O.D. phenol, when compared to GBFDS 272 (4.16). While VB type showed trace of O.D. phenol. With respect to total phenols, the mutants 28-1 (17.53) and 28-2 (15.86) showed significant superiority when compared to JL 24 (12.62) and inferiority when compared to GBFDS 272 (19.62). Whereas 45 (7.93) and VB type (4.17) contained low amounts of total phenol when compared to both JL 24 and GBFDS 272. All the resistant mutants 28-1 (177.6), 45 (222), VB type (277.5) and 28-2 (344.1) contained significantly low amounts of total sugars when compared to both GBFDS 272 (477.3) and JL-24 (455.10). Tanin was significantly high in 28-1 (129.6) and 45 (91.57), when compared to GBFDS 272 (83.25), whereas mutant 28-2 (84.91) was comparable to GBFDS 272, while mutant VB type showed less amount of tanin when compared to both JL-24 (74.09) and GBFDS 272 (Table 17).

4.7 Histology in selected groundnut genotypes

Plants have some mechanism for either avoiding or reducing the attack of herbivores. It is established that anatomical parameters greatly affect the ability of herbivore to attack in some plants. Therefore comparative histological studies of leaves of mutants (28-2, 45 and 110) along with parents (VL 1 and DER), resistant check (GBFDS 272) and susceptible check (JL 24) were undertaken to investigate the possible anatomical defence mechanism. Different anatomical parameters that were investigated were, thickness of leaf, thickness

Table 17 : Bio-chemical parameters in groundnut mutants.

Genotypes	Total phenol (mg/100gm)	OD phenol (mg/100gm)	Tanin content (mg/100gm)	Total sugars (mg/100gm)
1-1	13.36 e-g	7.07 e-g	101.61 a	373.00 g-i
2-1	13.35 e-g	5.83 c-e	121.54 a	379.01 g-i
2-2	18.78 a-c	8.12 fg	130.70 a	424.83 i-k
3-1	6.68 ij	3.12 a	65.76 ef	578.94 l
27-1	10.85 jh	6.45 d-f	111.28 a	153.15 a-c
28-1	17.53 b-g	6.45 d-f	129.60 a	177.60 b-d
28-2	15.86 b-g	4.58 a-c	84.91 bc	344.10 g
29-1	20.03 a	16.23 h	127.42 a	416.25 h-j
45	7.93 hi	5.20 b-d	91.57 b	222.00 de
78-1	14.19 d-g	Trace	66.60 fg	444.00 j-l
78-2	16.70 a-e	Trace	128.20 a	224.78 d-f
98-1	10.85 gh	4.12 a-c	69.92 e-g	180.38 b-d
109-1	15.86 b-g	5.82 c-e	89.90 b	185.93 b-e
110	7.51 j-h	3.95 ab	76.91 c-e	152.63 a-c
121	15.02 c-g	8.33 g	79.91 cd	344.10 g
139-1	15.86 b-g	6.49 d-f	105.72 a	199.80 c-e
161	17.53 a-d	6.66 d-g	90.74 b	369.08 gh
171	3.34 j	3.53 ab	64.10 gh	362.50 h=g
110(8)	16.69 a-e	3.33 ab	48.28 i	384.50 g-i
67-2	5.84 ij	2.91 a	63.27 gh	119.33 c-e
104-9	5.01 ij	3.32 a	51.61 i	135.25 ab
VB type	4.17 ij	Trace	69.09 e-g	277.50 fg
VL 1	5.84 ij	4.57 a-c	79.92 cd	235.88 e-g
DER	5.84 ij	3.95 ab	54.94 hi	238.65 e-g
JL 24	12.62 fg	7.49 e-g	74.09 d-f	455.10 j-l
GBFDS 272	19.62 ab	4.16 a-c	83.25 b-d	477.30 kl
GM	5.06	12.18	86.95	302.13
S.Em.±	0.63	1.31	3.34	18.24
C.D. at 5%	1.83	3.83	9.97	53.16
CV (%)	17.61	15.28	5.41	8.54

Value with same subscript do not differ at 5% level of significance.

of epidermis (Adaxial and Abaxial) along with cuticle, thickness of palisade, number of epidermal cells per mm and distance between phloem to epidermis.

4.7.1 Variance

Analysis of variance (Table 18a) revealed significant variation for all the characters under study.

As indicated by PCV, the variance was low for all the parameters (<17.5%) except for distance between phloem and epidermis (34.2%), for which variance was moderate. The same pattern of variation was conspicuous when GCV was considered as a parameter. The heritability (>70.5%) was high for all the parameters. GAM was moderate for thickness of abaxial epidermis along with cuticle (12.2 and 29.1%). Thickness of palisade (26.9%), number of epidermal cells in abaxial surface (27.9%) and distance between phloem to epidermis (221.6%), due to high heritability. Whereas it was low for rest of the characters (<17.6%) as an account of low magnitude of variation (Table 18b).

4.7.2 Mean performance

As noticed from the Table 19, the mutant 28-2 and 45 recorded lower total thickness of leaf, thickness of abaxial epidermis along with cuticle, thickness of palisade and number of epidermal cells per mm in abaxial surface of the leaf compared to rest of the genotypes. The mutant 45 recorded significantly higher thickness of adaxial epidermis along with cuticle compared to GBFDS 272, but comparable to JL 24 and parent VL 1. While mutant 28-2 was comparable to GBFDS 272 and parent DER. With respect to distance between phloem to

Table 18 : Variance and components of variability for histological parameters.

a : ANOVA.

Source of variance	Leaf thickness (μm)	Thickness of epidermis along with cuticle (μm)		Palisade thickness (μm)	Epidermal cells/mm		Distance from phloem to epidermis (μm)
		Adaxial	Abaxial		Adaxial	Abaxial	
Replication	0.4	1.4	0.4	0.2	6.7	1.0	12.3
Genotypes	1498.6 **	12.3 **	36.8 **	1211.7 **	24.6 **	54.3 **	11530.8 **
Error	0.0	1.4	2.7	1.4	1.4	1.2	37.6

*, ** - Indicate the significance at 5% & 1% probability respectively.

b : Genetic components of variance.

Source of variance	Leaf thickness (μm)	Thickness of epidermis along with cuticle (μm)		Palisade thickness (μm)	Epidermal cells/mm		Distance from phloem to epidermis (μm)
		Adaxial	Abaxial		Adaxial	Abaxial	
PCV	8.4	12.0	17.5	13.1	10.3	14.5	34.2
GCV	8.4	7.0	15.7	13.0	9.3	14.0	34.1
H	100.0	70.5	80.8	99.6	84.6	93.1	99.0
GAM	17.3	12.2	29.1	26.9	17.6	27.9	221.6

Table 19 : Histological parameters in selected groundnut genotypes.

Genotypes	Leaf thickness (μm)	Thickness of epidermis along with cuticle (μm)		Palisade thickness (μm)	Epidermal cells/mm		Distance from phloem to epidermis (μm)
		-----			-----		
		Adaxial	Abaxial		Adaxial	Abaxial	
28-2	249.01b	25.76bc	20.39bcd	149.19e	24.37c	25.62d	188.90c
45	226.47e	28.98a	19.32cd	128.80f	28.58b	23.64e	295.16a
110	269.40b	27.90abc	25.76a	156.67d	31.48a	28.93c	100.89f
VL 1	290.87a	28.98a	18.24d	164.22b	31.71a	36.39a	201.78b
DER	261.89c	24.68c	21.46bc	128.80f	32.12a	32.12b	126.65e
GBFDS 272	274.77b	24.67c	18.24d	161.00c	31.69a	30.44bc	169.58d
JL 24	286.58a	28.98a	26.83a	185.18a	28.07b	31.60b	186.76c
G.M.	265.57	27.14	21.46	153.40	29.71	29.82	181.39
S.Em. \pm	2.14	0.70	0.96	0.68	0.69	0.64	3.54
C.D. at 5%	6.59	2.16	2.97	2.12	2.13	1.97	10.92
C.V. (%)	1.39	4.48	7.79	0.17	4.04	3.71	3.38

Value with same subscript do not differ at 5% level of significance.

epidermis, the mutant 45 was significantly superior to all other genotypes, whereas mutant 28-2 was significantly superior to GBFDS 272, but comparable to JL 24. While mutant 110 recorded least distance compared to all other genotypes.

Though the genotypes differed for histological parameters, this difference cannot be associated with resistance to *Spodoptera litura* and thrips.

4.7.3 Association among pest, disease and histological parameters

Correlation coefficients among pest resistance parameters (DS, LDS, DT and NT), late leaf spot (LLS), rust (R) and histological parameters (thickness of total leaf (TTL), thickness of upper i.e., Adaxial epidermis (TUE), thickness of lower i.e., Abaxial epidermis (TLE), thickness of palisade parenchyma (TPP) and density of upper (DE) and lower epidermal (LE) were calculated and presented in Table 20.

Correlations among pest and disease resistance parameters with histological parameters revealed significant and positive association for number of thrips with total leaf thickness, damaged due to *S.litura* with lower epidermis cells per mm, and late leaf spot with number of lower epidermis cells per mm while, there was no significant association between any of the remaining parameters.

Table 20 : Correlations among pest resistance, disease resistance and histological parameters.

	TTL	TUE	TLU	TPP	UE/mm	LE/mm
DT	0.7228	-0.0099	0.4069	0.2882	0.4390	0.6859
NT	0.7739*	0.3093	0.5650	0.6625	0.4866	0.6832
DS	0.7389	-0.0219	0.2936	0.3025	0.6874	0.8686*
LDS	0.1394	0.5132	0.2113	-0.1034	0.5024	0.3894
LLS	0.6831	-0.0392	0.0921	0.3520	0.4211	0.8255*
R	0.1196	0.5860	0.1325	0.3638	0.2112	-0.0957

* Indicates significance at 1% probability.

DISCUSSION

V. DISCUSSION

There is an increased awareness in the world that agricultural practices must be sustainable. Plant breeding has an important role to play in sustainable agriculture. Duvick (1993) described the general needs of a sustainable agricultural system and included characteristics needed in cultivars for a such a system. These characters were, increased insect and pathogen resistance and adaptation to relatively unmodified soil and climatic conditions.

In India average yield of groundnut like in other developing countries remains well below the level achieved, in the country like U.S.A. wherein yield average 2800 to 3400 kg/ha but yields of 4500 kg/ha or more are common for top producers. These large yields and high returns are a product of intensive management. Constraints to production vary from place to place and system to system. In transitional tract of Karnataka defoliating insect *Spodoptera litura* (F.) would drastically effect the yield.

Heavy dependence on chemicals have created host of problems : resurgence of pest population; emergence of secondary pest out breakes as a consequence of elimination of beneficial insect species; increased cost of production and serious environmental pollution. Therefore need for development of resistant varieties has become high priority for groundnut breeders, as it is basic component and provides basic foundation for Integrated Pest Management (IPM). This approach is economically practicable, ecologically sound, socially acceptable and environmentally sustainable technology which is essential for developing countries like India.

At present in transitional tract of Karnataka all the cultivated varieties are susceptible to *S.litura* and thrips. The available resistant genotypes have undesirable agronomic attributes and hybridization is so far not successful in combining resistance along with agronomic characters. Therefore the present study was envisaged to screen and evaluate groundnut mutants against *S.litura* and thrips, to understand the biochemical and histological basis of resistance, besides studying growth and development of *S.litura* on selected genotypes.

5.1 Screening and evaluation of groundnut mutants against *Spodoptera litura* and thrips

A total of 26 genotypes (22 mutants + 2 parents + 2 checks) were raised in single row of 2.5 m length under unprotected condition in Randomised block with two replications. They were screened for *S.litura* and thrips during *Kharif* 1996 and summer 1997, respectively. The data on various resistance and productivity parameters are subjected to ANOVA. Results of screening and evaluation are discussed here.

The mutants derived from VL 1 differed significantly for all pest resistance parameters (DS, LDS, DT and NT) and showed high heritability indicating substantial amount of variation (Table 5a & b, 7a & b, 9a & b and 11a & b) and scope for selection for the resistance parameters.

The mutants 28-1, 28-2, 45, 98-1 and 110(8) were resistant to *S.litura* based on per cent leaf area damaged (Table 6 and Fig. 2). The same parameter was also used by Dhir *et al.* (1992), Patil *et al.* (1995) and Nadaf *et al.* (1995) for assessment of resistance in groundnut genotypes. The mutants 28-1, 28-2

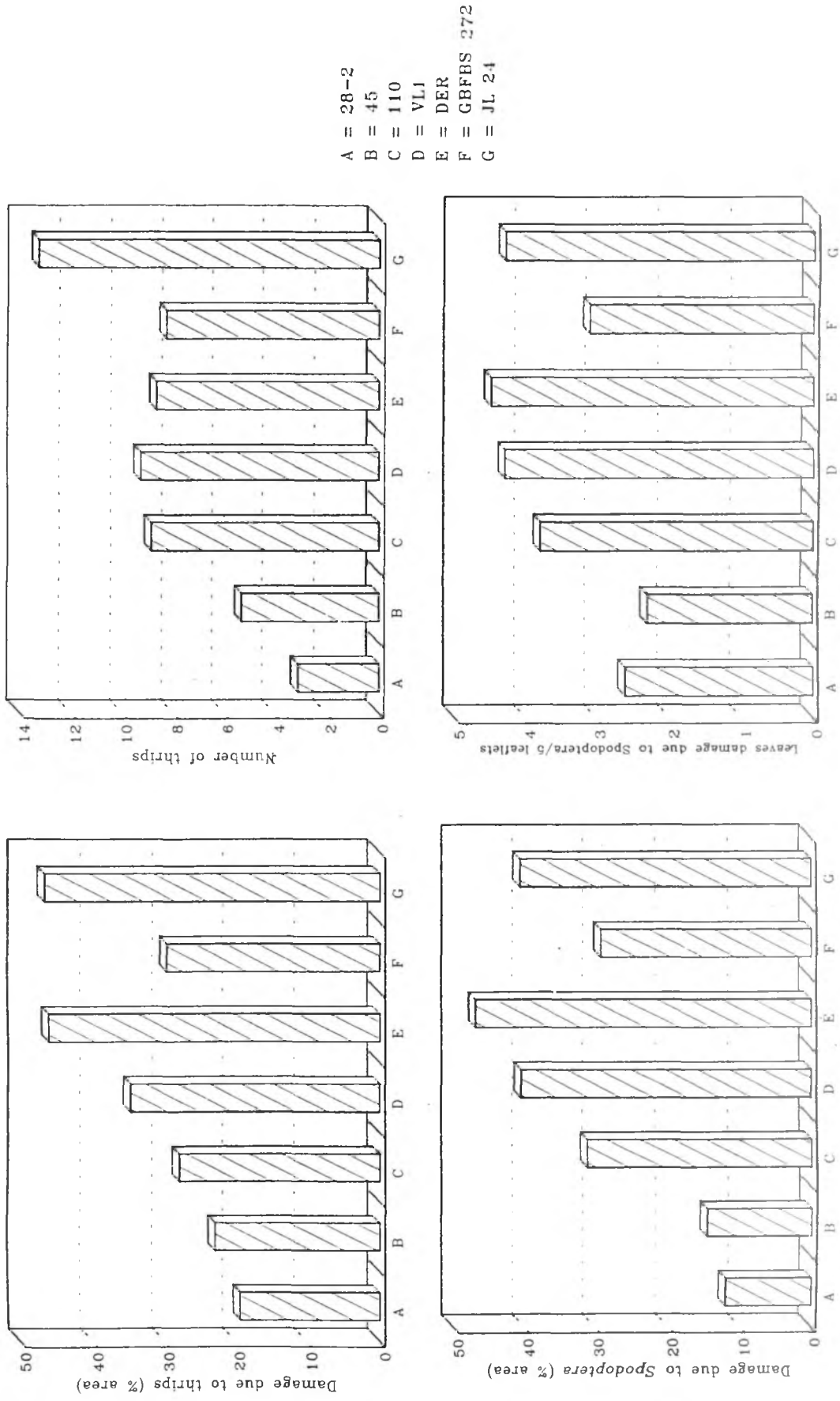


Fig. 2: Pest Resistance parameters in groundnut mutants.

and 45 were also resistant when leaflets damaged due to *S.litura* was considered (Table 6 and Fig.2). This parameter was used by Patil *et al.* (1991) for evaluating resistance. Between these two parameters per cent leaf area damaged was better criteria to judge resistance as evident from the magnitude of PCV, GCV, H and GAM (Table 5).

Besides 28-1, 28-2, 45 and 110 the mutant VB type was found to be resistant to thrips as they recorded low leaf damage due to thrips (Table 8 and Fig.2). This criteria was also used by Young *et al.* (1972); Kinzer *et al.* (1973); Stalker and Campbell (1983). The same set of mutants along with 78-2, 139-1, 2-1, 2-2, 110(8) and DER were resistant to thrips based on low number of thrips recorded in the unopened leaflets (Table 8 and Fig.2). This criteria was also used by Kennedy *et al.* (1992). When both the parameters were considered together, mutants 28-1, 28-2, 45, 110 and VB type were resistant to thrips. The combination of criteria was also used by Tappan and Gorbet (1979) and Amin *et al.* (1985). Among the two criteria number of thrips recorded in unopened leaflets was found to be a better criteria based on the magnitude of variance components PCV, GCV, H and GAM (Table 7b). The mutants 28-1, 28-2, 45 and 110 which were resistant to *S.litura* were also turned out to be resistant to thrips.

The three mutants 28-2, 45 and 110 which were resistant to both *S.litura* and thrips, having good productivity attributes were evaluated on large scale along with parents (DER and VL 1), released varieties (ICGV 86590, TMV 2 and Dh 40), resistant check (GBFDS 272) and susceptible check (JL 24) during *Kharif* 1996 against *S.litura* and during summer 1997 against thrips. All the

genotypes were raised in 5 rows of 5 m length during *Kharif* 1996 and 3 rows of 2.5 m length during summer, 1997 in two replications with Randomised block under unprotected conditions.

The resistance in these mutants against *S.litura* and thrips was reconfirmed (Table 10 and 12). There was no difference (*lon par*) between mutants and released varieties for plant yield, infact the mutant 110 was even superior to all other genotypes. Yield (q/ha) of mutants 28-2 and 110 was on par/comparable to released varieties, but yield of mutant 45 was slightly low because of the low plant population. The test weight of mutants was higher than released varieties as the seeds were bolder. The mutants took 105 days to mature. The maturity of mutants was comparable to released varieties but earlier than resistant check GBFDS 272 by 10 days (Fig.3). Thus the mutants would fit well for double cropping in transitional tract of Karnataka.

Therefore, the mutants 28-2, 45 and 110 could be tested extensively for direct release for cultivation or used as source material in future breeding programmes.

Among the mutants, pest and disease parameters were found to be associated as revealed by correlation study. The parameters damage due to thrips with number of thrips and number of leaflets damaged due to *S.litura*, number of thrips with leaf area damaged due to *S.litura* and number of leaflets damaged due to *S.litura*, and number of leaflets damaged due to *S.litura* with late leaf spot, were positively and significantly associated (Table 13). Therefore, there is a possibility of screening for *S.litura* or thrips avoiding screening for both. The leaflets damaged due to *S.litura* and late leaf spot were positively

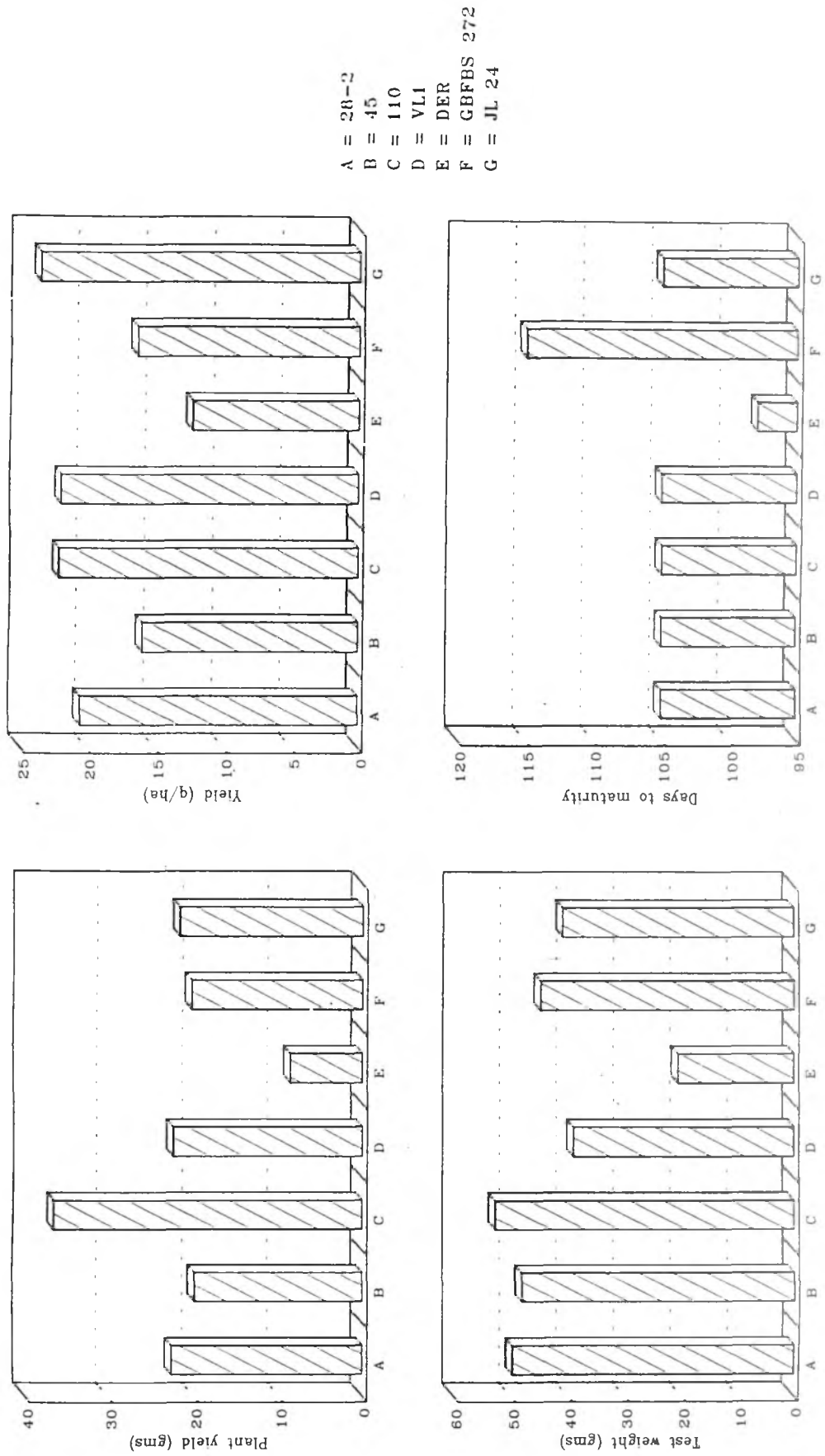


Fig. 3:Productivity parameters in groundnut mutants.

and significantly associated, indicating the scope for indirect selection for either resistance to *S.litura* or late leaf spot.

Generally a genotype is resistant to either pests/diseases. Oftenly in nature we do find genotypes resistant to both pests and diseases i.e., Multiple pest and disease resistant genotypes. These genotypes are of great importance in both integrated pest and disease management. They can be useful in reducing the yield loss due to pest and diseases without the usage of insecticides and fungicides. If these genotypes are also resistant to vectors of viruses, they will have an additional advantage of protection against viral diseases.

A variety of great potential in this respect is ICGV 86031 resistant to *S.litura* and vectors (Dwivedi *et al.*, 1993) and has confirmed resistance to viruses. The genotype ICGV 86388 is also resistant to vectors and viruses (Wightman and Ranga Rao, 1994). Another variety ICGV 87157 was confirmed to be resistant to late leaf spot, rust, *S.litura* and other pests (Nigam *et al.*, 1992). Some of the wild species and ICGV 87157 also exhibited multiple pest and disease resistance (Moss *et al.*, 1992).

The resistant mutants 28-2, 45 and moderately resistant mutant 110 with good productivity, pod and kernel features besides maturing early have additional advantage of having co-existence of pest and disease resistance parameters. That is, these mutants are resistant to pests, *S.litura* and thrips as well as resistant to foliar diseases late leaf spot and rust (Motagi *et al.*, 1996) (Fig.4). Therefore the mutants could be experimentally evaluated for BND which could be source material in breeding for multiple pest and disease resistance.

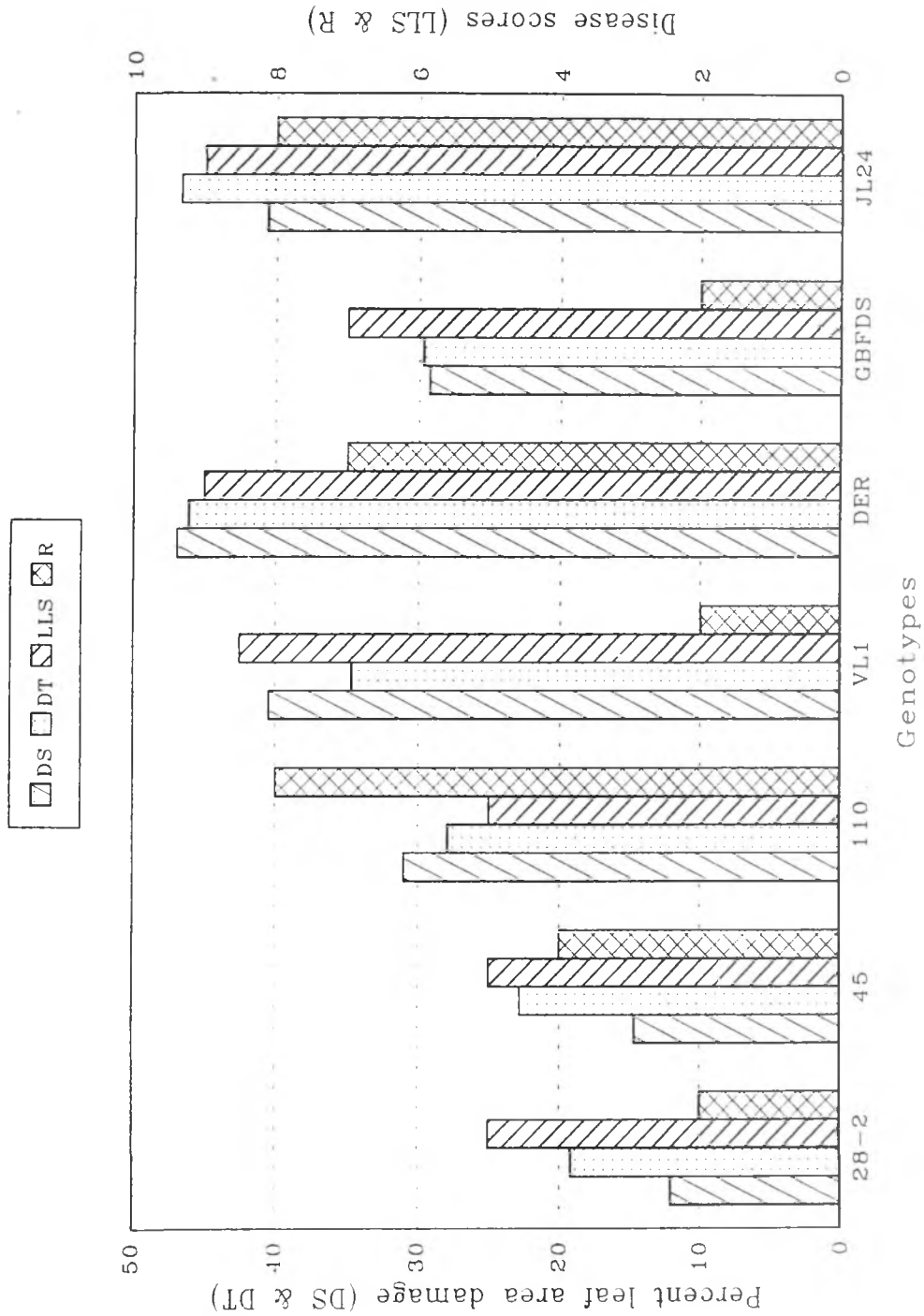


Fig. 4: Pest and disease resistance parameters in mutants.

5.2 Life history parameters of *Spodoptera litura* (F.)

Rearing lepidoptera for plant resistance research has become an integral part of many programmes, aimed at developing crop plants resistant to attack by these insects. The comparisons are based on estimations of either the effects of the insect pest on plant (i.e., leaf, fruit, or stem damage or yield loss) or the plant on the insect (i.e., reduced survival, slower growth, or increased developmental time). Therefore, in screening a plant for resistance to an insect, it is imperative that insect and plant be brought together in a way that the resulting interaction can be properly evaluated. Thus, creating a situation in which each plant has the same opportunity of being equally damaged and reducing the bias of screening results in field due to locomotory habit of *S.litura*.

The resistant mutants 28-2, 45 and 110 along with parents (VL 1 and DER), resistant check (GBFDS 272) and susceptible check (JL 24), were utilized for rearing of *S.litura*. The effects of these genotypes on number of larvae, per cent mortality of larvae, weight of the larvae, gain in weight of the larvae, number of pupae, per cent moth emergence, larval period and fecundity of *S.litura* were ascertained on each of the genotypes.

The present study demonstrated existence of substantial amount of variability in host effecting the life history parameters except pupal characters (Table 14a). The parameters number of larvae at two early stages (5 and 10 DAH), per cent mortality of larvae at first interval (15 DAH), weight of the larvae and gain in weight of the larvae at early stages (5 DAH) and number of eggs per case showed high heritability and genetic advance over mean (Table 14b), indicating scope for host selection.

The mutant 45 recorded lesser number of larvae and higher percentage of mortality throughout the life cycle (Table 15 and Fig.5). The per cent mortality of the larvae was very high in early stages indicating the vulnerability of neonate larvae to the existing resistant factor. According to Stevenson *et al.* (1993) neonate larvae should be a primary target in host plant resistance because plant damage can be minimised if the pest is eliminated as early in the life cycle as possible. The mutants 28-2 and 110, parent VL 1 recorded lesser number of larvae and higher percentage of mortality at two early stages (5 and 10 DAH). But the number of larvae at final stage (15 DAH) was comparable to other genotypes because of lower magnitude of early mortality. This indicates that, the later stage larvae are not affected by resistance mechanism. Such a phenomenon has also been observed with larvae of another species of lepidopteran insect *Heliothis zea* (Boddie) (Isman and Duffy, 1982). The development of first stadium larvae of *H.zea* was retarded by the presence of chlorogenic acid and rutin in artificial diets, whereas the third stadium larvae of the same species were not affected.

Though the effects on early mortality was greatest in mutant 45, the larvae on 28-2 showed significantly low weight and low gain in weight at all the stages of larval period (Table 15 and Fig.6). In contrast mutant 45 affected the weight of the larvae at two early stages and gain in weight at first interval, again indicating the effects of resistant mechanism on neonate larvae. These effects of mutants 45 and 28-2 on the larval survival at early stages and growth of larvae could obviously be, due to chemical factors, i.e., antibiosis, as elucidated by Painter (1951). The chemicals, viz., Quercetin glycosides, chlorogenic acid

□ 5 DAH ▨ 10 DAH ▩ 15 DAH

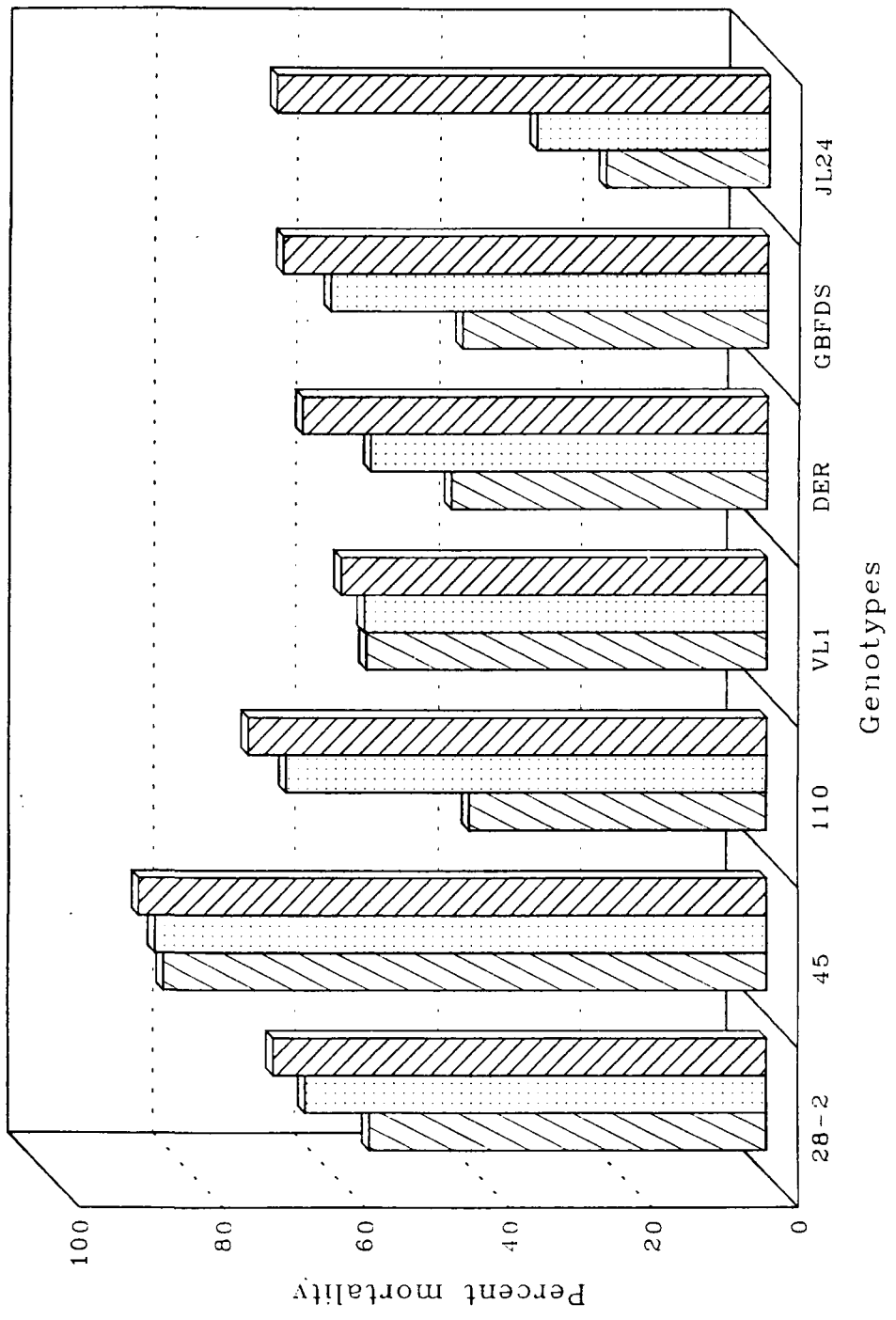


Fig. 5: Effect of groundnut genotypes on mortality of *Spodoptera litura* (F.)

□ 10 DAH □ 15 DAH

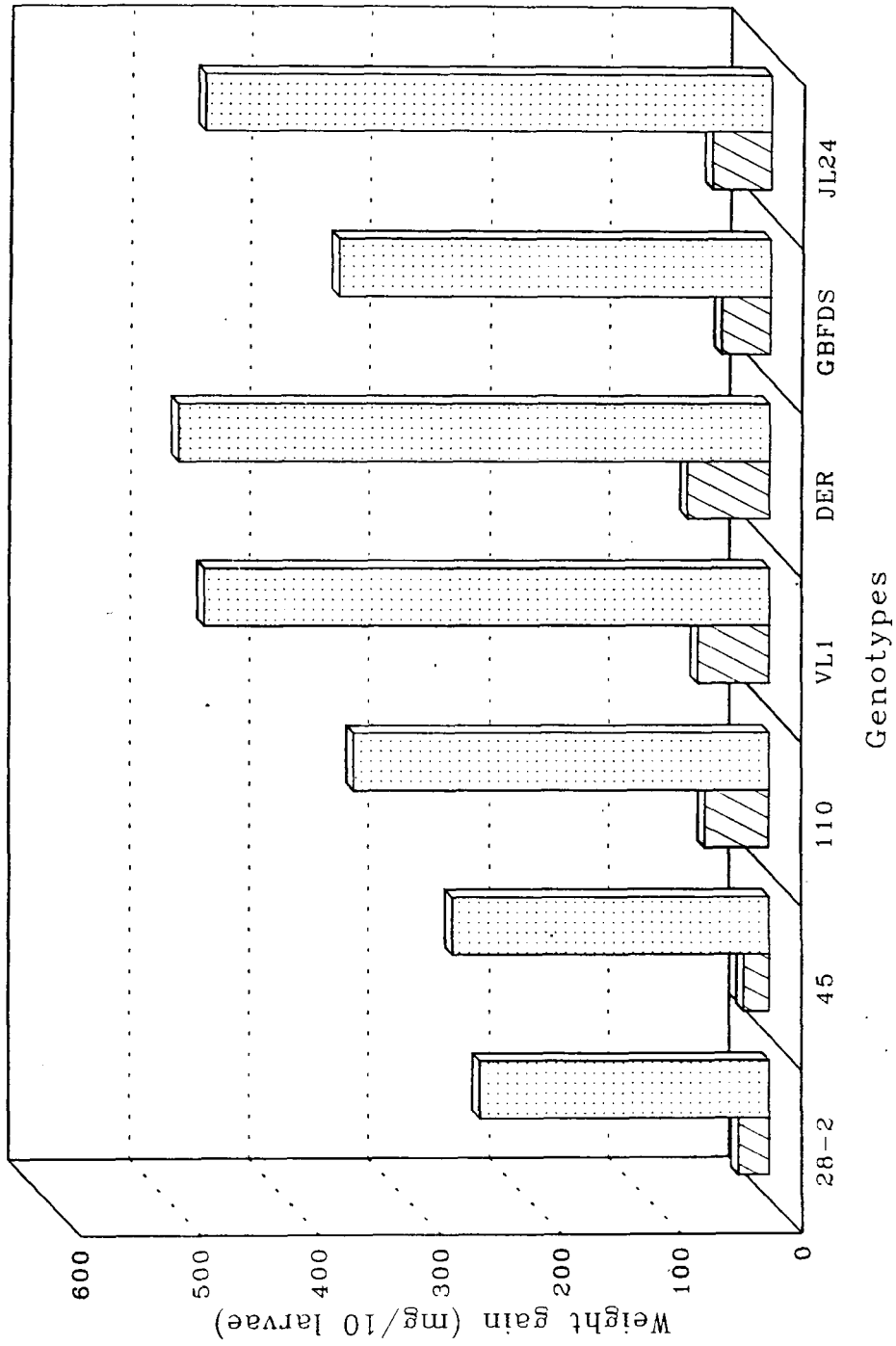


Fig. 6: Effect of groundnut genotypes on gain in weight of *Spodoptera litura* (F.)

and rutin responsible for resistance in wild *Arachis* species (Stevenson, 1993) could be the cause for antibiosis. However, physical resistance (leaf toughness) could also be important because the panitrometric studies showed that leaves of resistant wild *Arachis* species required a greater biting effort than did the leaves of susceptible TMV 2, and more susceptible species of *Arachis* (Stevenson *et al.*, 1993). But contradictorily, leaf toughness had negative relationship with per cent intensity of yellowing by jassids (Nandagopal *et al.*, 1993).

The differential response of mutant 45 and mutant 28-2 in reducing the survival in early stages and larval weight respectively may reflect the existence of altogether two independent mechanisms of resistance. Similar results were obtained by Stevenson *et al.* (1993), where first stadium larvae of *S.litura* on wild *Arachis* species were affected by factors different from those affecting the older larvae.

The resistance effects of mutants 28-2 and 45 did not affect number of pupae and per cent moth emergence (Table 15), which indicates the non-effectiveness of the resistant mechanisms at final stages of larvae and pupae. These results are in contradictory to results of Leuck and Skimmer, 1971 and Garner and Lynch, 1981, where mean percentage of pupae and moths were significantly less from larvae fed on foliage of the resistant cultivar, South Eastern Runner than susceptible cultivar Starr. And the pupal weights of male *S.frugiperda* tend to be greater than female on florunner groundnut.

The resistance in mutants 28-2 and 45 also affected the fecundity as indicated by total number of eggs laid by the moths developed from larvae fed

on resistant and susceptible genotypes which could be enormous (Table 15 and Fig.7). The maximum probable generation of *S.litura* could be 5 in a season. The difference between the cumulative eggs laid by moths developed from susceptible and resistant genotypes at the end of 5th generation (Prediction that half of the eggs develop into females) would give us the effect of resistance on fecundity of moths in a season. Therefore, the resistant effect of the mutant 28-2 and 45 foliage as the only food source could result theoretically in cumulative seasonal reduction of about trillions of eggs, larvae and adults in excess of that, which could be realized from larval feeding on foliage of the cultivar JL 24 alone. Painter (1951) stated that resistance at this level could be of high value as control measure. However there was no egg laying by moths developed from larvae fed on DER, which could be due to genotypic effect/ no proper sex ratio/ differential effects on two sexes/ extrinsic factors. Hence, a detailed examination of all these possible reasons is required for clear elucidation of the results.

The length of larval generation period (MLP) was also affected larvae fed on foliages of the resistant mutants 28-2 and 45 (Table 15 and Fig.8) which would further limit larval production. Estimates of number of generations per year have been placed as high as 11 (Vickery, 1929). A 3-day extension of MLP resulting from feeding on mutants 28-2 and 45 as observed in this investigation, theoretically could result in a single season in generation extension of 9 per cent. At the rate of 10 generation per year, nearly one generation could be omitted from the environment. In a 10 year period, at the same rate, almost 10-11 generations of the insect theoretically would not have reached

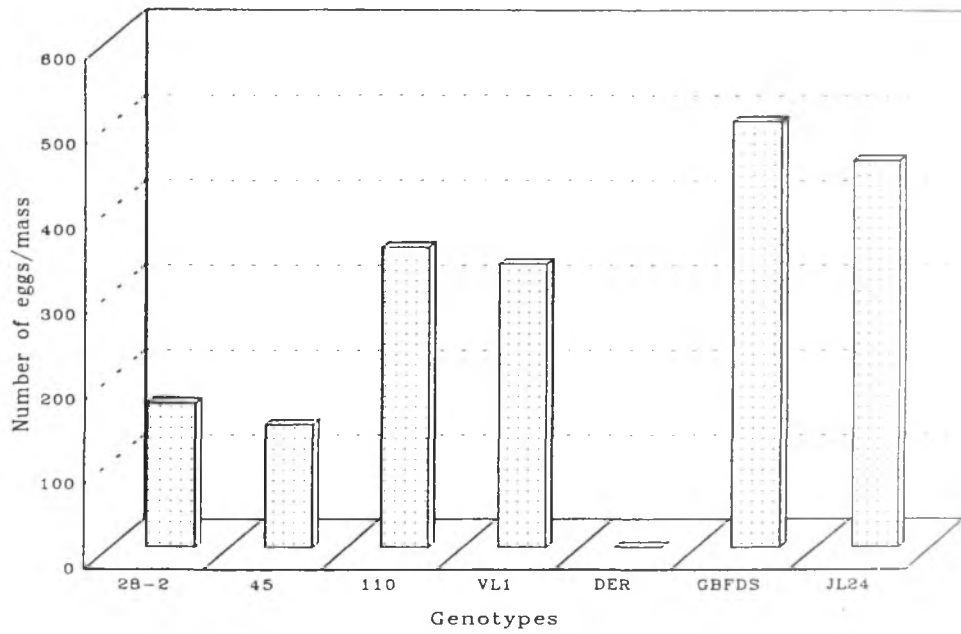


Fig. 7: Effect of genotypes on fecundity of *S. litura*.

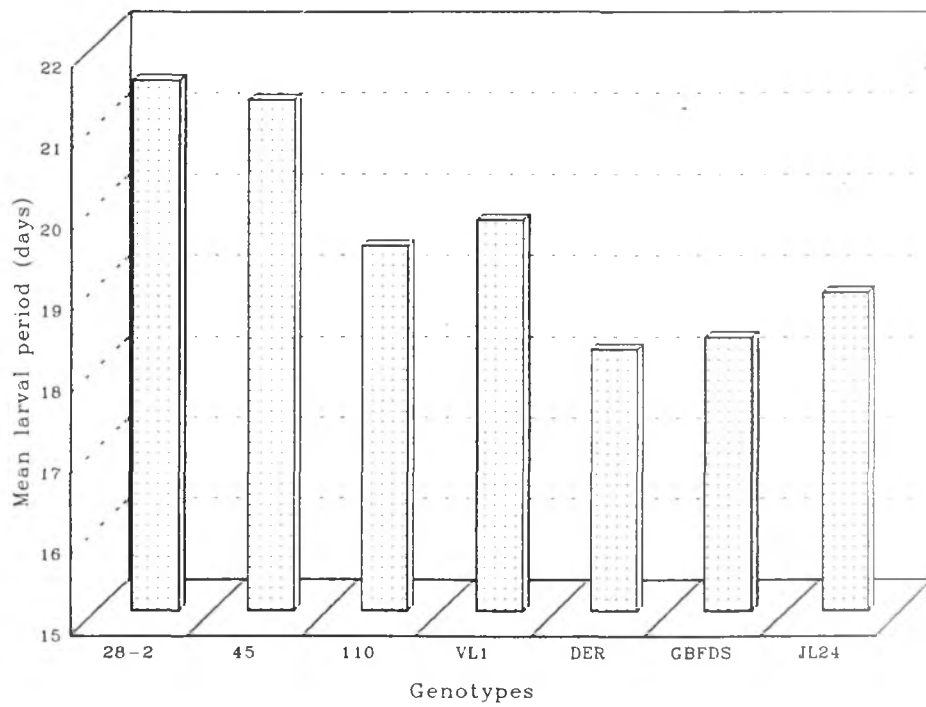


Fig. 8: Effect of genotypes on mean larval period of *S. litura*.

the environment. The same insect *S.frugiperda* fed with resistant flrunner took an average of 3.7 days more to develop compared to larvae fed with curly leaf (Todd *et al.*, 1991). The same insect also showed longer larval duration on NC Ac 2243 (Xie Jia Li, 1987).

Thus, the death of the insect on mutants 45 and 28-2 during neonate stage, was perhaps the most common and easily observable characteristic of antibiosis. The other characteristics viz., low gain in weight and extension of mean larval period and low rate of fecundity by moths of larvae fed on the foliages of these mutants (28-2 and 45) confirms the possible role of antibiosis as a mechanism of resistance in these mutants, as elucidated by Painter (1951). Of course many factors of environmental resistance cause fluctuations of insect populations, and they would also be affecting the insect populations in the field as well.

5.3 Biochemical basis of resistance

All the twenty two mutants along with parents (DER and VL 1), resistant check (GBFDS 272) and susceptible check (JL 24) were assessed for general group of biochemicals, viz., phenols, OD phenols, Tannins and total sugars in 70 day old plants during, summer 1997.

All the genotypes differed significantly and showed high heritability (Table 16a and b) indicating scope for selection for the biochemical parameters. Plant resistance to insects depends on different mechanisms, of which biochemical bases of resistance is one. The type of chemicals responsible for insect resistance are numerous but most commonly known groups are secondary

metabolites. The potential benefits from identifying a resistance mechanism are enormous. When a resistant trait has been identified, the screening process becomes quick and efficient. This also helps in screening in the absence of pest and it could revolutionize the breeding programme, allowing large amount of germplasm to be screened, as well as reducing the area and number of plants grown and crossed.

In the present investigation, though the genotypes differed for phenol, OD phenol, tannin and total sugars, but they were not associated with any of the insect resistant parameters (Table 13). Besides correlation, a detailed examination of biochemical parameters (Table 17) namely phenols, OD phenols, tannins and total sugars in resistant and susceptible genotypes did not reveal any association with resistance parameters. Studies of Rajgopal *et al.* (1988) and Singh *et al.* (1992) revealed non existence of relationship between phenols, nitrogen, potash and sodium carbonate with resistance in accessions V 40, Ah 6429, NC Ac 17840, NFG 79 and EC 21989 to *S.litura*. However rearing of *S.litura* on mutants, susceptible and resistant genotypes revealed possible existence of antibiosis, indicating the role of some specific chemical factors. Stevenson *et al.* (1993) have shown specific chemicals like queretin glycosides, coffeoylquinic acid, rutin and chlorogenic acids as possible reasons for resistance in wild species for *S.litura*. Lipids were also known to impart resistance to *S.frugiperda*. The growth of the *S.frugiperda* was enhanced when larvae fed with epidermal wax free diet made out of foliage from resistant *A.ipaensis* (Yang *et al.*, 1995).

Thus, there is a need to explore the role of specific chemicals like queretin glycosides, coffeoyl quinic acid, rutin, chlorogenic acid and epidermal wax in the resistant mutants.

5.4 Morphological and histological basis of resistance

Plants defend against herbivores by morphological and anatomical features. In groundnut the work on this aspect is very scanty. Study of Patil *et al.* (1995) has shown the association of higher total leaf thickness with resistant to *S.litura* in *A.monticola*. High trichome density, distribution and length have been shown to be important resistant factor in genotypes such as ICG 5040 (NC Ac 2214) and ICG 5043 (NC Ac 2240) for jassids (Campbell *et al.*, 1976; Dwivedi *et al.*, 1986).

The selected resistant mutants 28-2, 45 and 110 along with parents (DER and VL 1), resistant check (GBFDS 272) and susceptible check (JL 24) were included for histological investigation. The parameters, thickness of total leaf, thickness of epidermis along with cuticle (Adaxial and Abaxial), density of epidermal cells/mm (Adaxial and Abaxial) and distance between phloem and epidermis were studied on 70 day old plants during summer 1997.

Though the genotype differed significantly for anatomical parameters, the difference was not associated with resistance (Table 19). The correlation study (Table 20) also did not reveal any perceptible association with insect resistance parameters indicating the lack of role of these parameters in resistance to *S.litura* and thrips.

5.5 Future line of work

Based on information available and results of the present study, following future line of work can be proposed to develop agronomically preferred cultivars with resistance to pests.

1. The resistant mutants identified in the present investigation can be hybridized with high yielding cultivar to increase the productivity level of these mutants, since hybridization efforts with earlier material to combine resistance with high yield was not so very successful.
2. During rearing, mutant 45 recorded high percentage of larval mortality, whereas mutant 28-2 recorded low gain in weight. Therefore, these two characters have to be combined in resistance breeding to increase the extent and magnitude of resistance.
3. As revealed by biochemical, histological and rearing studies, the evidence of antibiosis operating in resistant mutants could be due to specific chemicals like quercetin glycosides, caffeoyl quinic acid, rutin, chlorogenic acid and epidermal wax (Stevenson, 1993; Yang *et al.*, 1995) which has to be confirmed in future.
4. As the mutants 28-2, 45 and 110 were resistant to thrips, which are vectors of viruses. These mutants should be experimentally evaluated for resistance to bud necrosis disease.
5. Biochemical (isozymes)/molecular markers (DNA) associated with resistance have to be identified so that the breeding process for resistance to insect pests becomes easy, quick and efficient.

SUMMARY

VI. SUMMARY

Insect pests particularly *Spodoptera litura* (F.) and thrips are major factors limiting the yield and quality of groundnut in transitional tract of Karnataka. Individually *S.litura* alone is capable of causing yield loss upto 60 per cent (Kulkarni *et al.*, 1989) and thrips can cause yield loss as a vector for Bud Necrosis Disease (BND) virus. These pests can be controlled by insecticides, but the most safest, effective and economical means of control would be, use of resistant varieties.

Research efforts have been successful in identifying resistant germplasm lines but most of them possess undesirable attributes. The hybridization effort is not so successful in combining the pest resistance with high productivity and other desirable attributes. In a mutation breeding programme with Dharwad Early Runner (DER) in our laboratory, a valencia line (VL 1) was isolated. Which on treatment with Ethyl Methane Sulphonate (EMS) yielded 22 secondary mutants, resistant to rust and/or late leaf spot. Some of the mutants also appeared to be resistant to *S.litura* and thrips. Hence, the present investigation was undertaken to systematically screen and evaluate mutants against *S.litura* and thrips, to understand histological and biochemical basis of resistance besides studying life history parameters of *S.litura*, when reared on selected genotypes.

The results of the present investigation have led to the following important conclusions.

All the mutants showed high magnitude of variation for the pest resistant parameters, damage due to *S.litura* (DS), number of leaves damaged due to *S.litura* (LDS), damage due to thrips (DT) and number of thrips (NT) as revealed by phenotypic and genotypic coefficient of variation. Heritability and genetic advance over mean was high indicating the scope for selection for these parameters.

Screening of 22 mutants along with parents (VL 1 and DER), resistant check (GBFDS 272) and susceptible check (JL 24) against high pest load of *S.litura* under unprotected condition during *Kharif*, 1996 indicated high level of resistance in mutants 28-1, 28-2, 45 and 110 (8) based on per cent leaf area damaged. Screening of the same material against thrips under unprotected condition during summer 1997 indicated high level of resistance in 2-1, 28-1, 28-2, 45, 110, 139-1 and VB type based on number of thrips in unopened leaves. Thus the mutants 28-1, 28-2 and 45 resistant to *S.litura* were turned out be resistant to thrips as well.

Among the resistant mutants 28-2, 45 and 110 possessed good pod and kernel features besides early maturing and were evaluated on large scale along with parents (DER and VL 1), varieties (ICGV 86590, Dh 40, TMV 2), resistant check (GBFDS 272) and susceptible check (JL 24) to assess the productivity potential.

The yield (q/ha) and shelling percentage of the mutants 28-2, 45 and 110 were comparable or on par with released varieties. The test weight of mutants was superior to released varieties as the seeds were bolder. There was no difference between mutants and released varieties for sound mature kernel per cent.

The maturity of the resistant mutants was comparable to released varieties (105 days). But, these mutants matured 10-15 days earlier than resistant check GBFDS 272, making them suitable for double cropping in transitional tract of Karnataka. Therefore, the mutants 28-2, 45 and 110 could be tested extensively for direct release for cultivation or used as a source material in future breeding programmes.

The mutant 45 recorded lesser number of larvae and higher percentage of mortality throughout the life cycle. The per cent mortality of the larvae was very high in early stages indicating the vulnerability of neonate larvae to the existing resistant factor. Death of neonate larvae is important in host plant resistance as the plant damage can be minimised if the pest is eliminated early in the life cycle. The mutants 28-2, 110 and parent VL 1 recorded lesser number of larvae and higher percentage of larval mortality at two early stages. But the number and mortality of larvae at final stage was comparable to other genotypes because of lower magnitude of early mortality. This indicates that the later stage larvae are not affected by resistance mechanism.

The mutant 28-2 showed significantly low weight and low gain in weight at all the stages of larval period. In contrast mutant 45 affected the weight of the larvae at the early stages and gain in weight at first interval, again indicating the effects of resistant factor on neonate larvae. The effects of 45 and 28-2 on the larval survival at early stages and growth of larvae could obviously be, due to chemical factors (i.e. antibiosis) as elucidated by Painter (1951).

The differential response of mutant 45 and mutant 28-2 in reducing the survival in early stages and larval weight respectively may reflect the existence of altogether two independent mechanisms of resistance.

The resistance effects of mutants was not observed on number of pupae and per cent moth emergence, which indicates the non-effectiveness of the resistant mechanisms at final stages of larvae and pupae.

The resistance effect of 28-2 and 45 was very much pronounced on fecundity of moths developed from larvae fed on these mutants. This could result in seasonal reduction of eggs, larvae and adults in excess of that which could be realised from larval feeding on foliage of susceptible cultivar. Resistance at this level could be of high value as a control measure (Painter, 1951). The existing resistant factor in 28-2 and 45 extended the larval period by 3 days which will also result in omission of the insect reaching the environment in a long run.

The vulnerability of neonate larvae is most common characteristic of antibiosis. The low fecundity, extension of larval period, and low gain in weight confirms the possible role of antibiosis as a mechanism of resistance in mutants 28-2 and 45.

The biochemical assay showed existence of high magnitude of variability and high heritability for all the biochemical parameters.

The genotypes differed significantly for phenols, OD phenols, tanins and total sugars but these were not associated with any of the insect resistance parameters. The detailed analysis of individual genotypes also failed to reveal any trend associated with resistance. This indicates the possible role of specific chemical

like queretin glycosides, coffeoyl quinic acid, rutin, chlorogenic acid and wax in existing resistance mechanisms in mutants.

The genotypes utilized in rearing of *S.litura* were involved in histological study. Though the genotypes differed significantly for anatomical parameters namely, thickness of total leaf, thickness of epidermis along with cuticle (Abaxial and Adaxial), thickness of palisade parenchyma, density of the epidermal cell/mm (Adaxial and Abaxial) and distance between phloem to epidermis, the differences were not associated with resistance. The correlation study also revealed lack of role of anatomical parameters in resistance to *S.litura* and thrips.

REFERENCES

VII. REFERENCES

- AMIN, P.W., 1983, Major field insect pests of groundnut in India and associated crop losses. *Proceedings of the National Seminar on Crop losses due to insect pests*, Hyderabad, A.P., India, 7-9 January, 1983, Eds. Krishnamurthy Rao, B.H. and Murthy, K.S.R.K., pp.337-344.
- AMIN, P.W. AND MOHAMMAD, 1980, Groundnut pest research at ICRISAT. *Proceedings of the International Workshop on Groundnut*, ICRISAT Centre, Patancheru, A.P. India, 13-17 October, 1980, pp.158-166.
- AMIN, P.W., SINGH, K.N., DWIVEDI, S.L. AND RAO, V.R., 1985, Source of resistance to Jassid (*Empoasca kerri* Pruthi), Thrips (*Frankliniella schultzei* (Trybon)) and Termites (*Odonto termes* Sp.) in Groundnut (*Arachis hypogaeae* L.). *Peanut Science*, 12:58-60.
- ANONYMOUS, 1977, *Annual Report*, ICRISAT, India.
- ANONYMOUS, 1980, *Annual Report*, ICRISAT, India.
- ANONYMOUS, 1981, *Annual Report*, ICRISAT, India.
- ANONYMOUS, 1984, *Annual progress report*, Groundnut. *XXVI Annual kharif oilseed workshop*, Directorate of oilseeds research, Rajendranagar, Hyderabad.
- ANONYMOUS, 1984, *Annual Report*, ICRISAT, India.
- ANONYMOUS, 1985, *Annual Progress Report*, *XXVII Annual kharif oilseed workshop*, Directorate of oil seeds research, Rajendranagar, Hyderabad.

- ANONYMOUS, 1986, *Annual Report*, ICRISAT, India.
- ANONYMOUS, 1986, *Annual report, Annual kharif oilseeds workshop*, Directorate of oilseeds research, Rajendranagar, Hyderabad.
- ANONYMOUS, 1995, FAO, *Quarterly Bulletin of Statistics*, 8:47.
- CAMPBELL, W.V., EMERY, D.A. AND WYNNE, J.C., 1976, Resistance of peanut to the potato leaf hopper. *Peanut Science*, 3:40-43.
- CAMPBELL, W.V., WYNNE, J.C., KEERATI KASIKORN, M., SIRISINGH, S., ADALLA, C. AND CADAPAN, E.P., 1987, Resistance of an international collection of peanut genotypes to insects in North Carolina, Philippines and Thailand. *Proceedings of American Society of Peanut Research and Education Society*, 19:14.
- CHOUHDARY, C.B. AND PRASAD, B., 1968, Genetic variation and heritability of quantitative characters in Indian mustard (*Brassica juncea*). *Indian Journal of Agricultural Sciences*, 38:3-10.
- DHIR, B.C., MOHAPATRA, H.K. AND SENAPATI, B., 1992, Assessment of crop loss in groundnut due to tobacco caterpillar *Spodoptera litura* (F.). *Indian Journal of Plant Protection*, 20:215-217.
- DUBOIS, M., GILLS, J.K., HAMILTON, P.A., REBERS AND SMITH, F., 1955, A calorimetric method for the determination of sugars. *Nature*, 168:167.
- DUFFEY, S.S. AND FELTON, G.A., 1991, Enzymatic antinutritive defences of the tomato plant against insects. In Naturally occurring pest bioregulators, Ed. Hedin, P.A. *Symposium 449 of the American Chemical Society*, Washington, D.C. pp.166-197.

- DUVICK, D.N., 1993, The role of seed companies in crop improvement. In Crop improvement for sustainable agriculture, Eds. M.B.Callway and K.A.Francis. pp.46-50.
- DWIVEDI, S.L., AMIN, P.W., RASHEEDUNNISA, NIGAM, S.N., NAGABHUSHANAM, G.V.S., RAO, V.R. AND GIBBONS, R.W., 1986, Genetic analysis of trichome characters associated with resistance to jassids (*Empoasca kerri* Pruthi). *Peanut Science*, 13:15-18.
- DWIVEDI, S.L., REDDY, D.V.R., NIGAM, S.N., RAO, G.V.R., WIGHTMAN, J.A., AMIN, P.W., NAGABHUSHANAM, G.V.S., REDDY, A.S., SCHOLBERG, E. AND RAMRAJ, V.M., 1993, Registration of ICGV 86031 peanut germplasm. *Crop Science*, 33:220.
- ELLIGER, C.A., WONG, Y., CHAN, B.G. AND WAISS, 1981, Growth inhibitors in tomato (*Lycopersicon esculentum* L.) to the tomato fruit worm, *Heliothis zea*. *Journal of Chemical Ecology*, 7:753-758.
- GARNER, J.W. AND LYNCH, R.E., 1981, Fall armyworm leaf consumption and development on florunner peanuts. *Journal of Economic Entomology*, 74(2):191-193.
- GOPALI, J.B., NADAF, H.L., PATIL, R.K., LINGAPPA, S., HANAMARATTI, N.G. AND SATTIGI, H.N., 1996, Larval and ovipositional behaviour of *Spodoptera litura* (F.) in response to resistant and susceptible cultivars of groundnut. *Crop Improvement*, 23:49-52.
- HANSON, C.H., ROBINSON, H.F. AND COMSTOCK, R.E., 1956, Biometrical studies of yield in segregating population of Korean Lespedse. *Agronomy Journal*, 48:267-282.

- ISMAN, M.B. AND DUFFEY, S.S., 1982, Toxicity of tomato phenolic compounds to the fruit worm, (*Heliothis zea*). *Entomologia Experimentalis et Applicata*, 31:370.
- JAYAPAL, R. AND MAHADEVAN, A., 1968, Biochemical changes in banana leaves in response of leafspot pathogenesis. *Indian Phytopathology*, 21:43-48.
- JENSEN, W.A., 1962, Botanical histochemistry principles and practices. W.H.Freeman and Co., San Francisco. pp.103-120.
- KENNEDY, F.J.S., RAJAMANICKAM, K., BALAGURUNATH, R. AND LOURDURAJ, A.C., 1992, Yield losses due to insect pests and their control in groundnut. *Groundnut News*, 42:7.
- KINZER, D.R., PITTS, J.T., WALTON, R.R. AND KIRBY, J.S., 1973, Thrips resistance in plant introductions and in selections made for peanut improvement in Oklahoma. *Journal of Economical Entomology*, 66:91-95.
- KULKARNI, K.A., 1989, Bioecology and management of *Spodoptera litura* (Fabricius) (Lepidoptera : Noctuidae) on groundnut (*Arachis hypogaea* L.). *Ph.D. Thesis*, University of Agricultural Sciences, Dharwad, India.
- KYI, A., ZALUKI, M.P. AND TITMARSH, I.J., 1991, An experimental study of early stage survival of *Helicoverpa armigera* (Lepidoptera : Noctuidae) on cotton. *Bulletin of Entomological Research*, 81:262-271.
- LEUK, D.B. AND SKINNER, J.L., 1971, Resistance in peanut foliage influencing fall armyworm control. *Journal of Economic Entomology*, 64:148-150.
- LUSH, J.L., 1940, Intra-sire correlation and regression of offspring on dams as method of estimating heritability of characters. *Proceedings of American Society, Animal Production*, 33:293-301.

- LYNCH, R.E., BRANCH, W.D. AND GARNER, J.D., 1981, Resistance of *Arachis* species to the fall armyworm, *Spodoptera fungiperda*. *Peanut Science*, 8:106-109.
- MOSS, J.P., MALLIKARJUNA, N. AND SINGH, A.K., 1992, Use of wild species in groundnut improvement In *Groundnut a global prospective*, Proceedings of an international workshop ICRISAT, November, 1991. Ed. Nigam, S.N. pp.415.
- MOTAGI, B.N., GOWDA, M.V.C. AND SHESHAGIRI, R., 1996, Mutants resistant to foliar diseases in groundnut (*Arachis hypogaea* L.). *Current Science*, 71(7):582-584.
- MOUSSA, M.A., NASR AND HASSAN, A.S., 1960, Factors affecting longevity and reproductive potentials of moths of the cotton leaf worm *Prodenia litura*. *Bulletin of Society of Entomology, Egypt*, 44:383-386.
- NADAF, H.L., PATIL, R.K., GIRIRAJ, K. AND HANAMARATTI, N.G., 1995, Field performance of groundnut genotypes with inherent resistance to biotic stresses. *Crop Improvement*, 22(2):261-263.
- NANDAGOPAL, V., MURTHY, T.G.K., RADHAKRISHNAN, T. AND SEN, P., 1993, Leaf toughness in relation to resistance to jassids *Balclutha hortensis* Lindb, in groundnut. *International Arachis Newsletter*, 13:20-21.
- NIGAM, S.N., REDDY, L.J., SUBRAMANYAM, P., REDDY, A.G.S., MC DONALD, D. AND GIBSON, R.W., 1992, Registration of ICGV 87157 an elite peanut germplasm with multiple resistance to diseases. *Crop Science*, 32(3):837.
- PAINTER, R.H., 1951, Insect resistance in crop plants. Macmillan Company, New York. pp.23-53.

- PANCHABHAVI, K.S. AND NETHRADHANI RAJ, C.R., 1987, Yield of groundnut as affected by varying larval density of *Spodoptera litura* Fabricius (Lepidopera : Noctuidae). *Indian Journal of Agricultural Sciences*, 57:525-527.
- PATIL, R.K., GOWDA, M.V.C. AND NADAF, H.L., 1991, Screening of Spanish bunch breeding lines of groundnut against *Spodoptera litura* (F.) damage. *International Arachis Newsletter*, 10:26-27.
- PATIL, R.K., NADAF, H.L., SATTIGI, H.N., HANAMARATTI, N.G., LINGAPPA S. AND GOPALI, J.B., 1995, Effect of groundnut genotypes on biology and development of *Spodoptera litura* (F.). *Crop Improvement*, 22:184-188.
- RAJGOPAL, K., NANDA GOPAL, N. AND BHAGAT, N.R., 1988, Preliminary screening of Virginia groundnut genotypes against tobacco caterpillar *Spodoptera litura* (F.). *Journal of Oilseed Research*, 5:162-165.
- RAMAKRISHNA, N., SAXENA, V.S. AND DHINGRA, S., 1984, Insecticide resistance in the population of *Spodoptera litura* (F.) in Andhra Pradesh. *Pesticides*, 18:23-24.
- ROBINSON, H.I., COMSTOCK, R.E. AND HRVEY, P.H., 1949, Estimation of heritability and degree of dominance in corn. *Agricultural Journal*, 41:353-359.
- SHESHAGIRI, R., 1994, Nature and utility of genetic variability in groundnut (*Arachis hypogaea* L.). *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Dharwad.
- SHIVASUBRAMANIAN, P. AND PALANISWAMY, G.A., 1986, Loss in yield due to leaf hoppers and thrips in groundnut. *Madras Agricultural Journal*, 73:530-531.

- SINGH, R.K. AND CHOUDHARY, D., 1979, *Biometrical methods in quantitative genetic analysis*. Kalyani Publication, Ludhiana. pp.55-90
- SINGH, K.N. AND SACHAN, G.C., 1992, Phenols and phenolic acids in groundnut (*Arachis hypogaea*) resistant to tobacco caterpillar. *Indian Journal of Agricultural Sciences*, 60:717-719.
- SINGH, V.J., NANDAGOPAL, V., GOR, H.K., CHIKANI, B.M. AND JAROLI, R.K., 1993, BG2 a possible donar parent for resistance to *Helicoverpa* and *Spodoptera*. *Groundnut News*, 5:2-3.
- SITHANATHAN, S., SOHATI, P.H. AND SYAMASONTA, B., 1991, Groundnut genotypes less susceptible to insect pest damage in the SADCC regional variety trials in Zambia and Malandi. *International Arachis News Letter*, 10:28-30.
- STALKER, H.T. AND CAMPBELL, W.V., 1983, Resistance of wild species of peanut to an insect complex. *Peanut Science*, 10:30-33.
- STEVENSON, P.C., 1993, Biochemical resistance in wild species of groundnut (*Arachis*) to *Spodoptera litura* (Lepidoptera : Noctuidae). *Bulletin OILBISROP*, 16:155-162.
- STEVENSON, P.C., BLANEY, W.M., SIMMONDS, M.J.S. AND WIGHTMAN, J.A., 1993, The identification and characterization of resistance in wild species of *Arachis* to *Spodoptera litura* (Lepidoptera : Noctuidae), *Bulletin of Entomological Research*, 83:421-429.
- SUBRAMANYAM, P. AND McDONALD, D., 1982, Groundnut rust, its survival and carry over in India. *Proceeding of Indian Academy of Sciences*, 91:93-100.

- SWAIN, T. AND HILUS, W.E., 1959, The phenolic constituents of *Prunus domestica* L. The quantitative analysis of phenolic constituents. *Journal of Social and Food Agriculture*, 10:63-68.
- TAPPAN, W.B. AND GORBET, D.W., 1979, Relationship of seasonal thrips population to economics of control on florunner peanuts in Florida. *Journal of Economic Entomology*, 72: 772-776.
- TEICH, L., 1969, A new approach to the control of *Spodoptera littoralis*. Biosdural in peanuts in Israel. *Israeli Journal of Entomology*, 4:139-143.
- TIWARI, S.N., BHATTACHARYA, A.K., RATHORE, Y.S. AND SACHAN, G.C., 1991, Dry matter utilization of groundnut varieties by *Spodoptera litura* (Fabricius). *Indian Journal of Entomology*, 53:516-517.
- TIWARI, S.N., RATHORE, V.S. AND BHATTACHARYA, A.K., 1981, Interenstic rate of increase of *Spodoptera litura* (F.) on different varieties of groundnut. *Science and Culture*, 47:261-262.
- TIWARI, S.N., RATHORE, V.S., BHATTACHARYA, A.K. AND SACHAN, G.C., 1989, Classification of groundnut varieties based on growth reaction of *Spodoptera litura* (F.) and mahalanabis D² Statistics. *Indian Journal of Entomology*, 50:202-208.
- TODD, J.W., BEACH, R.M. AND BRANCH, W.D., 1991, Resistance in eight peanut genotypes to foliar feeding of Fall Armyworm, Velvet bean caterpillar and corn earworm. *Peanut Science*, 18:38-40.
- VAN EMDEN, H.F., 1980, In Insects and mites of legume crop. (R.J. Summerfield and A.E. Bunting eds.). Royal Botanic Gardens, Kew, England. pp.187-197.

- VICKERY, R.A., 1929, Studies on fall armyworm in the Gulf Coast District of Texas. *USAD Technical Bulletin*, 138:63.
- WATSON, J.R., 1922, The flower thrips. *Florida Agricultural Experiment Station Bulletin*, 162:42-43.
- WIGHTMAN, J.A. AND RANGA RAO, G.V., 1994, Groundnut pests In: The groundnut crop : A scientific basis of improvement, Ed. Smart, J. Published by Chapman and Hall, London.
- WIGHTMAN, J.A., DICK, K.M., RANGA RAO, G.V., SHANOWER, T.C. AND GOLD, C.G., 1990, In Pests of groundnut in semi arid tropics, Ed. Singh, S.R. Chichester, J. Wiley & Sons. pp.243-322
- XIE JIA LI, 1987, Influence of peanut cultivars on the development and feeding activity of the common cut worm *Spodoptera litura* (F.). College, Laguna, Philippines, Philippines University Las Banas College, Laguna, pp.68.
- YANG, G., ESPELIE, K.E., TODD, J.W., CULBREATH, A.K., PITTMAN, R.N. AND DEMSKI, J.W., 1995, Characterisation of cuticular lipids from cultivated and wild peanuts species and their effect on feeding by fall armyworm (Lepidoptera : Noctuidae). *Peanut Science*, 22:49-54.
- YOUNG, S., KINZER, R.E. AND WALTON, R.R., 1972, Field screening for thrips resistance in peanuts. *Ibadan Review*, 64:828-32.

EVALUATION OF GROUNDNUT MUTANTS FOR RESISTANCE TO *Spodoptera* AND THRIPS

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ABSTRACT

The present investigation was carried out to identify genotypes resistant/tolerant to *Spodoptera litura* and thrips, besides good productivity attributes. The 22 mutants derived from VL 1 were screened against *S. litura* during *Kharif* 1996 and against thrips during Summer 1997 along with susceptible (JL 24) and resistant (GBFDS 272) checks.

The mutants 28-1, 28-2, 45 and 110 were resistant to *S.litura*. Along with these, the mutants 2-1, 139-1, and VB type were also found to be resistant to thrips.

The mutants (28-2,45 & 110) possessed good pod and kernel features and matured early by 10 to 15 days than resistant germplasm. The above features of mutants (28-2,45 & 110) were comparable to popular Spanish Bunch varieties cultivated in Karnataka. The mutants 28-2, 45 and 110 showed high level of resistance to leaf spots and variable level of resistance to rust, indicating their potentiality in genetic improvement of groundnut for multiple pest and disease.

In laboratory rearing of *S.litura* on selected genotypes the mutant 45 recorded lesser number of larvae and higher percentage of mortality throughout the life cycle. The mutant 28-2 showed significantly low larval weight and low gain in weight at all the stages of larval period indicating the possible existence of two independent mechanisms of resistance. The mutants 28-2 and 45 extended the larval period by 3 days and affected the fecundity of moths as well reflecting the possible role of antibiosis as a mechanism of resistance.

The genotypes showed significant variation for various leaf anatomical parameters but no perceptible association with resistance was evident. The genotypes also differed significantly for general group of chemicals *viz.*, phenols, OD phenols, tanins and total sugars but their differences were not associated with resistance to *S.litura* and thrips indicating the possible role of specific chemical factors in antibiosis.

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