STUDIES ON THE GROUNDNUT POD BORERS

By

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THESIS SUBMITTED TO THE
DHRA PRADESH AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE
IN THE FACULTY OF AGRICULTURE

DEPARTMENT OF ENTOMOLOGY
COLLEGE OF AGRICULTURE, RAJENDRANAGAR
ANDHRA PRADESH AGRICULTURAL UNIVERSITY
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August, 1992

CERTIFICATE

Ms. V. Anitha has satisfactorily prosecuted the course of research and that the thesis entitled **STUDIES ON THE GROUNDNUT POD BORERS** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by her for a degree of any University.

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This is to certify that the thesis entitled "**Studies on the groundnut pod borers**" submitted in partial fulfilment of the requirements for the degree of '**Master of Science in Agriculture**' of the Andhra Pradesh Agricultural University, Hyderabad, is a record of the bonafide research work carried out by Ms. V. Anitha under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

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

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ACKNOWLEDGEMENTS

I have no words to express my profound gratitude to Dr. D.D.R. Reddy, Professor and Head, Department of Entomology, College of Agriculture, APAU, Rajendranagar, the Chairman of my advisory committee for his invaluable guidance and constant supervision during the course of my study. I take this opportunity to thank him for the interest he has taken to give me the right perspective of research.

My special thanks are due to Dr. G.V. Ranga Rao, Legumes Entomologist, ICRISAT, for his close monitoring and expert guidance throughout my research work.

I express my sincere thanks to Dr. T.V.K. Singh (Asst. Professor, Dept. of Entomology) and Mr. K. Srinivasulu Reddy (Asst. Professor, Dept. of Statistics and Mathematics) for the valuable help rendered during the period of my work.

I am grateful to the staff of the Department of Entomology, College of Agriculture, APAU, Rajendranagar, for their unstinted cooperation.

I deem it a privilege to thank Dr. D.L. Oswalt, Program Leader, Human Resource Development Program and Dr. J.A. Wightman, Principal Legumes Entomologist, ICRISAT, for permitting me to avail the facilities at ICRISAT.

I am grateful to Dr. S.N. Nigam, Principal Plant Breeder, Groundnut Breeding for permitting me to sample in the fields of the Unit.

I appreciate the assistance and cooperation extended to me by all the staff of Legumes Entomology throughout my research work at ICRISAT. My special thanks are due to Mr. V. Anjaiah, Mr. V.J. Benny, Mr. Eswaraiah, and Mr. Manaiah.

I am extremely thankful to Mr. B.V.R. Sastry and Mr. S.V. Prasad Rao for the help rendered in the excellent computerization of the thesis. My special thanks to Mr. Chitnis of Photographic Unit, who did a neat job with photographs and added colour to my thesis.

I am highly indebted to Mr. A.K. Sadasivan, Genetic Resources Unit, ICRISAT, for his endless support and encouragement throughout my study period.

Last but not the least, I take great pleasure in acknowledging the support given by my mother and grandparents in completing my work.

I am grateful to all my well wishers and friends especially Vijaya, Kumar, Krishna, Padma, Srinivas, and Venkat who enthusiastically stood by me at all times.

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DECLARATION

I declare that this thesis entitled **STUDIES ON THE GROUNDNUT POD BORERS** is a bonafide record of work done by me during the period of research at ICRISAT, Patancheru. This thesis has not formed in whole or in part, the basis for the award of any degree or diploma.

Date: 24-8-1992

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Degree to which it is submitted	:	MASTER OF SCIENCE IN AGRICULTURE
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Year of submission	:	1992

Abstract

Investigations were undertaken on pod feeding insects of groundnut at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India, during the rainy and postrainy seasons of 1991-1992 on the species involved, their nature and extent of damage. In addition to ICRISAT Center, farmers fields in some important groundnut growing areas of southern India were also surveyed to know the distribution and extent of damage by these pests. The pod borers identified were earwigs (*Euborellia annulipes* Lucas, *E. plebeja* Dohrn, *Forcipula quadrispinosa*), termite (*Odontotermes wallonensis* Wasmann), wireworm (unidentified), subterranean ant (*Dorylus labiatus* Shuckered), tobacco caterpillar (*Spodoptera litura* F.), white grub (*Lachnosterna consan-guinea* Blanch), and a curculionid grub (unidentified). Of these, earwigs were predominant.

At ICRISAT the vertisols recorded about 26 per cent damage in rainy season whereas the alfisols showed about 2 per cent damage in both rainy and postrainy seasons. The surveys indicated that pod feeders caused an average of less than 2 per cent damage. The distribution of earwig was more in vertisols whereas the other pod borers were more prevalent in alfisols. The damage symptoms by each pod borer was described based on position, size, and shape of holes on the pod, nature, extent of damage to kernel, and also other distinguishing features like type of excreta, and nature of plugging in the pod. A key based on these characters was formulated for identifi-cation of the pod borers of groundnut.

INTRODUCTION

CHAPTER I

INTRODUCTION

Arachis hypogaea L. (groundnut or peanut) is mainly used as a dietary supplement in the developed countries either as roasted and salted and eaten as a snack or as milled products. However, groundnuts are an important source of dietary protein and lipid, especially in developing countries. In India, the world's largest producer of groundnut, the oil is of prime importance as a cooking medium (Wightman and Amin, 1988), and in recent years this crop has gained a lot of importance due to shortage of edible oil. In India groundnut is grown in about 8 m ha producing 7.2 million tonnes of pods with an average yield of 900 kg ha^{-1} (FAO, 1990). This reflects 45 per cent of the total oilseeds area contributing 55 per cent of the total oilseeds in the country (NRCG, 1987). Although this crop occupies a unique place in the country's oilseed production the import of edible oil has gone up from time to time to meet the demand.

Insect pests are recognized as one of the major constraints in groundnut production (Gibbons, 1980; Vikram Singh, 1980). Pests of groundnuts were first extensively reviewed by Feakin (1973); later Smith and Barfield (1982) listed 356 taxa known to be associated with the crop. Recently Wightman and Amin (1988) briefly discussed pests of groundnuts grown in the semi-arid tropics and Amin (1988) reviewed the Indian situation. More recently Wightman *et al.* (1990)

categorized four cohorts of insects affecting groundnut, non-viruliferous foliage feeders, viruliferous foliage feeders (virus vectors), invertebrates living in the soil that feed on underground plant parts; and those that feed on the harvested and stored pods and kernels. Of these, the virus vectors and soil insects are the most insidious. The soil insects are seldom detected before they have caused considerable damage. Soil inhabiting insects can attack the pods, the roots or both. Pod feeders, sometimes though do not affect the yields directly, can increase the risk of aflatoxin contamination caused by the invasion of *Aspergillus flavus* (McDonald and Harkness, 1967)

Once penetrated by insects, pods are of little value because the kernels will be destroyed by the same insects or by members of another species, or by fungal contamination. Losses caused by boring insects can go undetected if they damage immature pods which rot, and disappear before harvest (Wightman and Amin, 1988). The groundnut pod borers mostly include a wide group of insects belonging to different orders of class Insecta. They are mainly the earwigs, termites, wireworms, false wireworms, white grubs, subterranean ants, *Spodoptera* etc. Common problem often encountered in pod borer studies is finding the causal organism at the damage site. Based on the damage symptoms, determining the pest is not an easy task unless one has a clear picture of the species involved. Very little is known about these pod borers, particularly their nature and extent of damage and their biology. Keeping in view the importance of pod borers, the present investigations were undertaken with the following objectives:

1. Collection, identification and determination of pest status of different pod borers;

2. Description of symptoms of attack by each pod borer pest.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

2.1 GROUNDNUT POD BORERS

Groundnut pod borers are an assorted range of arthropods belonging to various orders. Both adult and immature stages are responsible for the pod boring. An attempt has been made to review the available literature on the groundnut pod borers. However, the control aspect has been omitted in the present review.

Earwigs as pod borers of groundnut were reported by Cherian and Basheer (1940). They found *Euborellia stali* Dohrn. feeding on groundnut kernels by boring into the pods at Coimbatore, India. They stated that Burr (1910) observed the association of this earwig with groundnut in Madras and Pondichery in India. It has been suggested that it may be more widely distributed in southern India (Cherian and Basheer, 1940). More recently, Das and Ray (1988) reported another species *E. annulipes* Lucas as pod borer in Tripura. In Israel, *Anisolabis* sp., was reported boring into immature pods (Melamed-Madjar and Sholomo, 1970). Singh *et al.*, (1990) found *Labidura bengalensis* Dohrn as a minor pest associated with groundnut crop from peg initiation to harvest at the Indian Agricultural Research Institute, New Delhi.

Johnson and Gumel (1981) reported termites as pod borers in Africa. In a survey conducted in northern Nigeria between 1977 and 1979, *Microtermes lepidus*

Sjorstedt was found to cause extensive damage by attacking the pods, tap root and haulms. They were found to bore and scarify pods approaching maturity (Johnson *et al.*, 1981). Reddy and Sammaiah (1988) observed *Odontotermes brunneus* (Hagen) to bore into the main stem close to ground level, tunnel down into the tap root and up into the stem, at Warangal, India. Termite also damaged pegs and scarified mature pods and occasionally penetrated into their shells.

Wireworms (Coleoptera: Elateridae) and false wireworms (Coleoptera: Tenebrionidae) can be dealt with together because the convergence of their evolution that led to their morphological similarity extends to their predeliction for groundnut pods (Wightman *et al.*, 1990). Wireworms of the genus *Heteroderes* were found by Bass and Arant (1973) damaging peanut pods in Alabama. Larvae of the genus *Cebria* were also collected from peanuts. Although definite proof was lacking, it was probable that *H. laurentii* Guer. was the species attacking peanuts.

Wightman (1989) collected larvae of 14 wireworm species, including *Prosephus* spp., *Pseudolophoeus protensus* Gerstaeker, *Cardiophorus* sp and *Dyakus* sp at Malawi. None of the 16 possible species of false wireworms has been identified beyond the subfamily level. All these are primarily borers.

Both the wireworms and false wireworms were found damaging groundnut pods and newly sown seed at ICRISAT Center, but their identity and those of others in Asia are not known. The false wireworm species boring pods in southern

Africa has been identified as *Gonocephalum* spp. (Wightman and Amin, 1988, Wightman *et al.*, 1990).

The southern cornroot worm, the larva of 12 spotted leaf beetle *Diabrotica undecempunctata howardi* Barber (Chrysomelidae) commonly called spotted cucumber beetle was found to damage young peanut pods in Virginia (Fink, 1916). A related species *D. balteata* Lec., was found to be predominant as pod borer in Alabama (Bass and Arant, 1973).

In 1982 a severe outbreak of *Diabrotica speciosa* (Germar, 1824) was reported by Lourencao *et al.* (1982) during the dry season groundnut crop in Urania, Sao Paulo, Brazil. Though the adults of this insect are known to feed on the foliage, this was thought to be the first record of the larvae damaging roots and pods.

With respect to the white grubs (Coleoptera: Scarabaeidae) the larvae of *Strigoderma arboricola* (F.) have been reported causing serious damage to peanuts in Virginia (Miller, 1943). The grubs attacked peanut pods and often devoured the kernels. Only two species were found to be important in India *Lachnosterna (=Holotrichia) consanguinea* Blanch. mainly in the light alluvial soils of northern India and *L. serrata* F. throughout the subcontinent. *Maladera* sp. is the most abundant white grub in northern Thailand and another unidentified species has been found in northeast Thailand. The white grubs were found to destroy pods at all stages of development (Wightman *et al.* 1990).

Millipedes e.g., *Peridontopyge* spp. are mainly a western Africa problem, although they have been found associated with damaged pods in Malawi and Thailand (Wightman and Amin, 1988). Masses (1981) reported six species of millipedes of which *Peridontopyge rubescens* Attems and *Syndesmogenus mimeuri* Brolemann were the most abundant and are major pests of groundnut damaging the developing pods and also seedlings. Earlier Demange (1975) gave an account of 13 species known to damage groundnuts in Senegal.

Another insect belonging to Hymenoptera which has been identified as a pod borer is the subterranean ant, *Dorylus orientalis* Westwood. This was found to penetrate or perforate the groundnut pods and consume the internal contents, in Asia including India (Roonwal, 1975). This species was also observed for the first time associated with pod boring at ICRISAT (ICRISAT, 1987). Singh *et al.* (1990) also reported *D. orientalis* as a major pest of groundnut showing pod boring habit at Indian Agricultural Research Institute, New Delhi. Another *Dorylus* spp. which is common throughout southern Africa also showed similar damage symptoms as *D. orientalis* (Wightman and Amin, 1988).

Spodoptera litura (Fabricius) larvae (order: Lepidoptera), primarily defoliators mostly during the postrainy season were also found feeding on pods (Wightman and Amin, 1988).

Das and Ray (1988) reported *Etiella zinckenella* Treit. as an occasional pod borer of groundnut in Tripura apart from earwig and red ant.

2.2 EXTENT OF DAMAGE

The extent and intensity of damage are difficult to pinpoint in the case of pod borers because the different pod borers like earwigs, termites, millipedes, wireworms, ants etc. cause similar damage. By the time the damage is discovered at harvest time most of the pod borers disappeared, hence the literature on extent of damage by a particular pod borer is scanty.

Cherian and Basheer (1940) observed that infestation of pods by earwig *Euborellia stali* Dohrn., ranged from 2.7 per cent to 19.95 per cent. Counts of the attacked pods taken at the time of harvest of groundnut in different fields at three areas indicated 2.7-6.1 per cent at Palur, 6.2-13.5 per cent at Tindivanam and 9.6-19.95 per cent infestation at Coimbatore.

Purushottaman *et al.* (1970) reported as high as 46.6 per cent pod infestation. The matured pods were infested to an extent of 44.1 per cent, the intensity of infestation in case of immature pods was 52.1 per cent in Asirya muitunde, a variety of groundnut. A total loss of 114 kg of oil ha^{-1} was registered. Similar high infestation of *Anisolabis annulipes* (= *E. stali*) to the extent of about 40 per cent of bored pods has been observed on the susceptible genotypes in a vertisol field at ICRISAT (ICRISAT, 1986).

Das and Ray (1988) recorded pod borer incidence as high as 30 per cent and in some samples the average was 9 per cent in Tripura. The borers associated were

E. annulipes, D. orientalis, and *Etiella zinckenella*. *Euborellia annulipes* was also reported as a major pest inflicting 63 per cent damage to pods in Manipur (Barwal, 1985), in a study on the seasonal incidence of the pod borer on fortnightly sowings from April through August. Barwal and Gupta (1991) indicated that the incidence was low in the first three sowings and increased in the summer with increased moisture availability due to rains and decreased from 15th July onwards.

Generally termite damage is estimated in terms of pod scarification and plant mortality, since the termites are not primarily borers, damage caused due to boring alone may be difficult to record. Nevertheless, a report showing 46 per cent bored pods was given in Madhya Pradesh (Kaushal and Deshpande, 1967). Johnson and Gumel (1981) reported 8-41 per cent yield loss in the Sudan Savannah of Nigeria by *Microtermes lepidus* Sjorstedt, which attacked the pods (scarifying and boring). In the trials at Sebele Research Station, Gabarone, Botswana, groundnut plants from seeds that had not received any insecticidal treatment had 64 per cent sound pods. Of the remainder, about 15 per cent were perforated by termites, 11 per cent scarified, and 10 per cent totally destroyed (Wightman *et al.*, 1990).

As far as the order Coleoptera is concerned, the larvae of *Gonocephalum* spp. (false wireworm) can clearly damage many pods during their long developmental period, even though their density rarely exceeds 10/100 plants (Wightman, 1989). When their density is added to that of other pod borers (millipedes, termites, ants, and white grubs) this cohort may destroy many pods during a cropping season. Central Malawi was hard hit by this group of insects, with one for every two plants in some places (Wightman *et al.*, 1990). In 1947, Arant observed as high as 35 per cent of the pods injured, mostly by wireworm *Heteroderes* sp. (Bass and Arant, 1973).

Damage to roots and pods of the groundnut plants by the larvae of the southern corn rootworm, *Diabrotica speciosa* was such that the crop had no commercial value in Brazil (Lourencao *et al.*, 1982).

Gough and Brown (1988) showed that one white grub (*Lepidiota* sp.)/3 m row (about 15 plants) caused a loss of pods equal to 44 kg ha^{-1}. Earlier to this 85 per cent loss was reported in Virginia (Bass and Arant, 1973) by the white grub *Strigoderma arboricola.*

Millipedes contributed to an yield loss of 10-35 per cent by damaging seedlings and developing pods, besides reducing quality of harvested pods (Masses, 1981).

Keerati-kasikorn and Singha (1986) in a study conducted in 1985 on the incidence of subterranean ant, *Dorylus orientalis* Westwood, reported to be a serious problem in Thailand, observed the damage to occur and increase from the 8th week until maturity. The observations were taken from the seventh through thirteenth week after emergence. Pod damage was found to range from 15-48 per cent, with an average of 31.6 per cent.

2.3 NATURE OF DAMAGE

Cherian and Basheer (1940) observed the earwig *E. stali* boring into tender pods and feeding on kernels. In Israel, *Anisolabis* spp. were found to make holes in immature pods (Melamed - Madjar and Sholomo, 1970).

The pod boring by earwig results in either mouldy seed, premature germination or the rejection of a consignment in the wholesale market (Wightman *et al.*, 1990).

Purushottaman *et al.* (1970) reported that while pulling out the plants, pods exhibited holes of different sizes, plugged with excreta, sand particles and discoloured pulp. Generally one or two insects were found in the pod. The pest was observed to bore the pod at all stages of pod development.

Fungus growing termites (Macrotermitinae) are important pests of groundnut in Africa and India. They not only remove the nonfibrous outer layer of shell (scarification) (McDonald and Harkness, 1963) but also enter pods. They also attack the tap root, causing wilting and premature death (Perry, 1967). In Nigeria, damage to pods was caused by *Microtermes* spp. which usually entered the pod just behind the beak, leaving one or more small rounded holes in the shell approximately one mm in diameter. They occasionally attacked the kernels, apparently preferring the spongy inner lining of the shell, which they replaced with soil. Penetration of pod occurred independent of attack on the tap root. Pods penetrated by *Microtermes* were often lost in the final yield, since even if kernels were left intact, they were subsequently invaded and spoiled by pathogenic fungi. Furthermore, in those varieties with no seed dormancy, this form of attack sometimes resulted in premature germination (Johnson, *et al.*, 1981).

Wireworms and false wireworms damage groundnut pods by boring through the shell and eating the seeds (Wightman *et al.*, 1990). In case of *Diabrotica* larva, they were also found to attack pods and devour the seeds inside (Fink, 1916).

White grubs when they are small sever fine roots often close to the tap root of the groundnut resulting in loss of water absorbing area. As they grow these can cut the entire tap root resulting in plant mortality. They can often stunt plants. They also destroy pods at all stages of development (Wightman *et al.*, 1990). Similar types of damage were also stated earlier by Bass and Arant (1973).

The larvae of *Schizonycha africana* (Lap) (Coleoptera: Melolonthidae) did not make a distinct entrance into the pod, but consumed large parts of it. They may have attacked the adventitious roots (Johnson *et al.*, 1981).

The immature stages of the millipede, *Peridontopyge* spp. penetrated the shell, leaving a small round hole 1-4 mm in diameter. They fed on the inner lining of the shell and developing kernel. The size of the entrance hole often distinguished millipede attack from that of *Microtermes* (Johnson *et al.*, 1981).

Wightman and Amin (1988) reported that the millipedes *Peridontopyge* spp. are more likely to damage or destroy younger pods. They are mainly a western Africa problem although the authors have found millipedes associated with damaged pods in Malawi and Thailand. Wightman observed that the size of the holes depended on the body diameter of the millipede and that the developing seed is not always damaged (Wightman, 1989).

Neat 3 mm diameter holes in the pods were observed to be the damage of *Dorylus* spp. in the botanic garden of ICRISAT. The seeds were removed from the pods (Wightman, 1989).

In a study conducted to study the distribution and habit of *D. orientalis* at Pak Chong, Nakho Ratchasima, Thailand, it was observed that the subterranean ant formed passageways underground at a depth of 20-25 cm which may protrude underneath the groundnut plants. The ants bore into groundnut pods and fill the pods with the soil after feeding on seeds. However, no ant nest was found at the site (Thailand Coordinated Groundnut Improvement Program Progress Report, 1987).

Spodoptera litura primarily a defoliator was noticed as a pod borer in the light soils of northern India. Presumably, when the larva seeks shelter during the day it is able to follow the pegs to the pods through the friable soil (Wightman *et al.*, 1990). Similar damage was also observed at ICRISAT (Wightman *et al.*, 1987).

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

3.1 LOCATION OF EXPERIMENT

Studies on the incidence of groundnut pod borers, their nature and extent of damage were undertaken in the vertisols and alfisols at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, near Hyderabad, Andhra Pradesh, India, in the rainy and postrainy seasons during 1991-92. Two fields were selected, one representing vertisol (BUS1B and 1C) and the other alfisol (RUS6B) in the rainy season. Both the fields were located in the pesticide-free zone of the farm. In the postrainy season BP15 (vertisol - pesticides were applied for foliar pests) and RUS6B (alfisol) were sampled for pod borers. Recommended agronomic practices were followed to raise the groundnut crop. The date of sowing, area of the fields, and the varieties used are given in Table 1.

Table 1. Groundnut fields, varieties, sowing dates, and the area in different seasons.

Season	Field	Sowing date	Variety	Area (ha)
Rainy	BUS1B & 1C	17.07.91	TMV 2, ICG(FDRS) 10	2.0
	RUS6B	27.06.91	ICGS 44	0.8
Postrainy	BP15	27.11.91	ICGS 11, ICGS 44, ICGS 37, ICGS 65, ICGS 76, ICG 2271, ICGV 86599, ICG(CG)S 49, ICG(FDRS) 10.	2.0
	RUS6B	18.12.91	ICGS 44	0.8

3.2 SAMPLING FOR EXTENT OF DAMAGE

During the rainy season, weekly sampling was done in both vertisols and alfisols, the sample size being 100 plants field^{-1}. The plants were uprooted at random, following a zig-zag pattern to avoid bias. The damage was assessed by counting the total number of pods plant^{-1} and total number of pods damaged by pod borers. The sampling commenced from 25.9.91 and was done seven times in both the alfisols and vertisols till harvest. The same procedure was followed in the postrainy season, but only two samples were taken, one 15-days before harvest and the other at harvest to record the pod borer incidence, since the field belonged to breeding unit where another experiment was in progress. The damaged pods were separated from the plants and were collected in polythene bags for further examination.

3.3 COLLECTION OF POD BORERS

At the time of sampling groundnut plants for pod borer damage, the soil in the rhizosphere was examined for the presence of insects associated with pod boring. Soil examination was done with a magnifying lens by spreading the soil collected on a polythene sheet. The pod borers so collected were preserved in glass vials containing 70 per cent alcohol and labelled. Some of the specimens collected were reared in plastic cups of 7.5 cm filled with soil up to 3 cm with a diet of mature and immature pods. This was done mainly to ascertain whether these insects were associated with pod boring and also to study the nature of damage by the particular species of the insect. Earwigs, wireworms, and an unidentified curculionid grub were reared in this manner. The specimens were released singly into the cup till the completion of life cycles. The pods were changed on alternate days to avoid rotting and fungal infection.

3.4 IDENTIFICATION OF POD BORERS

The earwigs were identified by Dr. V.C. Kapoor, Professor, Department of Zoology, Punjab Agricultural University, Ludhiana. Red ants associated with pod boring have been identified by Dr. Mustaq Ali, Department of Entomology, University of Agricultural Sciences, GKVK Campus, Bangalore 560065. Termites were identified based on the key available at ICRISAT. Wireworms and curculionid grubs could not be sent for identification because of non availability of adults and only a few specimens of immature forms available.

3.5 NATURE OF DAMAGE

The pods collected in the field for assessing the extent of damage and also those collected from other fields such as RM8A (Botanical Gardens), RM16, RP3, RP9, RP10, and RP13, at the time of harvest at ICRISAT were first examined for external symptoms in the fields. They were again examined under the microscope to record further details which are generally overlooked on routine field observations. The bored pods were examined for the size and the shape of the aperture, the position of the bore, the most favoured spot of boring, any signs of scraping around the hole, and the content of the bore hole i.e., plugged with mud or its excreta or frass or without any of these. Wherever the plugging was observed, the material used for plugging was carefully removed with a needle or forceps placed on a paper and its composition was ascertained. For this purpose the plugged material was transferred to a small petri dish and examined based on its solubility. For examination of internal symptoms the pod was split open and pattern of damage was studied under the microscope - whether the insect in question was directly feeding on the kernels or on the endocarp first. The pods were examined for the presence of the kernels or for their remnants and for the pathways made from the entrance hole to the kernel. The pattern of damage, the first kernel to be attacked (i.e., preference), size and shape of feeding bore on kernel, and the presence of extraneous material like soil in the pod or the kernel - all these aspects were studied in detail under the microscope and the rough figures of these were noted down. Whenever a typical symptom was observed colour photographs were taken to aid the description.

For the study of excreta, in the case of earwigs, a circular piece of white paper was cut to fit into the bottom of the plastic cup and an earwig was released into it with a pod for its food. The next day the paper was removed and examined for the presence of excreta.

3.6 SURVEY

A survey of some of the groundnut growing areas of Andhra Pradesh, Tamil Nadu and Karnataka was taken up in the first week of April 1992. In Andhra Pradesh, the districts of Nalgonda, Khammam, Nellore, Chittoor, Kurnool and Ananthapur; in Tamil Nadu - south and north Arcot districts; and in Karnataka - Raichur district were covered. The survey facilitated the coverage of pod borer incidence in different soil types from light red, gravelly, sandy to black soil. The survey sites were selected at random taking as criteria the main groundnut growing areas of southern India and no importance was given to soil types and climatic conditions. Similarly the route followed was not predetermined. The travel was by road, making it easy to stop at fields by the roadside and recording the relevant observations and talking to farmers. In each district 2 or 3 fields were covered in different villages. Five to ten plants were uprooted randomly and the pods examined for the damage. If damage was seen then the surrounding soil was searched with the help of a scoop for the presence of the pod borers. The damaged pods were collected in grip-bags and labelled (name of the village and date of collection). This procedure was followed when the crop was in the field or when it was being harvested. In case of a harvested crop about 50 pods were collected randomly from the sun-drying pods in the field, and the amount of damage was assessed.

In some places, the pod borers found inside the pods while sampling, were preserved in vials with AGA solution (60 per cent alcohol + glycerine + acetic acid 10:1:1). The farmers' opinions about the incidence and the extent of damage done by pod borers were also collected.

After the tour, the bored pod samples collected were studied to categorize them on the type of damage done to associate them with the appropriate insect.

Prior to this trip another survey was undertaken from 1-3 March 1992 around Bapatla, Guntur District, Andhra Pradesh covering Vetapalem and Chirala and incidence of this group of pests was recorded. Here also 50 random pods were taken from the harvested pods left for sundrying in the fields.

RESULTS

CHAPTER IV

RESULTS

4.1 POD BORERS ASSOCIATED WITH GROUNDNUT

The pod borers associated with groundnut pods at various stages of the crop at ICRISAT as well as during surveys indicated (given in the extent of damage, Table 3, 4, and 5) earwigs, termites, wireworms, subterranean ants, tobacco caterpillars, white grubs and curculionid grubs as pod borers. Earwigs were found to be dominant species in both vertisols and alfisols more so in the vertisols. Wireworms were not specific to any soil, whereas termites and white grubs were observed only in alfisols. Subterranean ants and curculionid grub have been recorded from alfisols. However, tobacco caterpillar was more prevalent both in vertisols & sandy soils. The insect specimens identified are given in Table 2.

Table 2. Pod borers found associated with groundnut.

Pod borers recorded	
Identified	Unidentified
Earwigs: *Euborellia annulipes* (Lucas) *E. plebeja* (Dohrn) *Forcipula quadrispinosa*	Wire-worms
Termites: *Odontotermes wallonensis* (Wasmann)	Curculionid grub
Red ants: *Dorylus labiatus* (Shuckerd)	
Tobacco caterpillar: *Spodoptera litura* (F.)	
White grub: *Holotrichia consanguinea* (Blanch.)	

4.2 SURVEY FOR GROUNDNUT POD BORERS

Observations on pod borer fauna were taken in 35-farmers' fields and at Research Stations in the groundnut growing areas of south India mainly Tamil Nadu, Karnataka and Andhra Pradesh. The percentages of incidence were estimated. Based on the bored pods, 52 per cent of the farmers' fields had pod borer incidence out of which 26 per cent of the fields had negligible pod borer damage (< 1%), 20 per cent of the fields had around 5 per cent pod damage and 6 per cent of the fields had around 10 per cent pod damage (Table 3).

Among the pod borers, earwigs were found to be predominant in alfisols and vertisols of Tamil Nadu and Karnataka and in Andhra Pradesh the alfisols showed increased activity of termites. The wireworms were restricted to Chittoor district of Andhra Pradesh. *Spodoptera* larvae assumed a major role as a pod borer pest in the coastal sandy areas of Andhra Pradesh. The subterranean ants were noticed in Peddagottigallu village of Chittoor district. However, the incidence was negligible. All these observations were based mostly on symptoms and not on the actual presence of causal organisms except in the case of subterranean ants and wireworms. In general, the groundnut farmers in these areas are aware of the occurrence of the pod borers but have not taken up any control measures (except one farmer in Unchouda village of Karnataka applied Thimet @ 4.5 kg ha^{-1} at the time of sowing). In the survey conducted around Bapatla, Andhra Pradesh, during postrainy season 1991-92 for pod borers, only *Spodoptera* was found associated

Table 3. Survey for groundnut pod borer incidence in farmers' fields during postrainy season (April 1-8, 1992).

Location	Soil type	Cultivar	Pod damage (%)	Remarks
ANDHRA PRADESH				
NALGONDA				
Inupamula	Sandy red	TMV 2 (80 days)	6	Termite (2%), Earwig (4%)*
Ketipalli	Sandy red	TMV 2 (90 days)	2	Earwig (2%)
Vaira	Sandy red	JL 24 (close to harvest)	Nil	
KHAMMAM				
Laxmipuram	Light red	Bunch (close to harvest	Negligible	Pinhead size holes causal organism?
Mallela	Light red	TMV 2 (close to harvest)	Nil	
GUNTUR				
Karlapalem	Sandy	TMV 2	5	Earwig and *Spodoptera*
NELLORE				
Ulavapadu	Sandy red	TMV 2 (harvested)	< 1x	Termite damage with scarified pods and sand filled pods.
Bodanu	Sandy red	JL 24 (90 days)	10	Mostly termites. Very few wireworms in pods
Chenugunta	Sandy	JL 24 (harvested)	Negligible	Causal organism?
CHITTOOR				
Bandapalli	Light gravelly	TMV 2 (100-days)	5	Very small external holes visible after a thorough wash of pods. Pod flesh entirely scraped off. Lot of frass and discolouration. One wireworm found. Termite infested pods (scarified as well as bored) were found.
Kanigiri	Red gravelly	TMV 2 (50 days)	Nil	
Jakkalavaripalli (Tirupathi)	Clay loam	TMV 2 (100 days) JL 24 (100 days)	Nil	
Peddagottigallu	Light sandy	JL 24 (Harvesting)	Negligible	Termite, red ant and wireworm (2 Nos.)
Sanjivapalli		K 3 (50 days)	Nil	
ANANTAPUR				
Nallaboyinapalli		Local bunch (90 days)	10	Earwig
Brahmanapalli	Red gravel	Local bunch (100 days)	Nil	
Mannila	Red gravel	Local bunch (120 days)	5	Termite and earwig
KURNOOL				
Aluru (Adoni)		TMV 2 (50 days)	Nil	
Kuppugallu (Adoni)		Local bunch (harvesting)	Nil	

Table 3 (cont)

Location	Soil type	Cultivar	Pod damage (%)	Remarks
MAHBOOBNAGAR				
Kotagadara	Black clay	Local bunch (150 days)	Negligible	Earwig, wireworm?
Rajapur	Light red	TMV 2 (close to harvest)	Negligible	Earwig, wireworm?
TAMIL NADU				
Chingulput	Sandy loam	TMV 2 (80 days)	Nil	-
Saram (Tindivanam)	Light clay	TMV 2 (harvested)	5	Earwig
Veerareddy-kuppam (Vriddhachalam)	Light red	VRI 2 (close to harvest	Nil	Farmers reported that pod borer damage could be seen mostly in Aug-Sep and Feb, and the insect locally known as "Marvattu".
Aladi	Light red	VRI 2 (close to harvest)	4	Termite, earwig, wireworm? (based on the damage symptoms)
Ramanathapuram Res. Stn. farm	Light red	VRI 2 (close to harvest)	Nil	-
Kodima (S. Arcot)	Black	Local bunch (close to harvest)	< 5	Termite damage on young pods.
Morukolam (Tiruvannamalai)	Black	JL 24 (close to harvest)	Nil	-
Muniyandangala	Light latrite	Local bunch (close to harvest)	Negligible	Earwig
KARNATAKA				
RAICHUR				
Unchouda	Black clay	Local bunch (120 days)	Nil	Thimet applied.
Kasbe Camp	"	K 3 (harvested)	< 1	Earwig?
Bapur	Gravelly light red	ICRISAT var. (50 days)	Nil	
Res. Stn. Farm	Light red	ICRISAT var.	Negligible	
Vijayanagar Camp	Black clay	Local bunch (harvested)	Nil	
Sitanagaram Camp	Black clay	Harvested	Nil	

*Based on 50 pods.

with groundnut pod damage. In some fields the pod damage appeared to be more than 10 per cent.

4.3 EXTENT OF DAMAGE

Groundnut pod borer damage was recorded at ICRISAT Center in alfisols and vertisols during the rainy and postrainy seasons of 1991-92 and the data on per cent damaged pods and the insects associated with damage are presented in Table 4 and 5.

In general, the incidence of pod borers was low and ranged between 1.35 and 2.79 per cent in alfisols. Earwigs, termites, white grubs were the predominant pod borer fauna associated with this damage. Earwigs contributed more damage compared to termites and white grubs. However, termite damage increased with the age of the crop. It was also observed that the damage due to borers was more or less consistent irrespective of age of crop (90-128 days after sowing (DAS)) and did not indicate clear cut trend in the progress of the damage.

In vertisols the number of bored pods were relatively higher during rainy season compared to alfisols. Observation at 73 DAS showed 2.19 per cent damaged pods and the damage increased to 26.14 per cent by harvest (Table 4). As in alfisols, earwigs were the dominant species followed by wireworms.

The observations on pod borer incidence were recorded in the alfisols as well as vertisols, but in the latter the incidences were recorded on eight groundnut varieties. Observations recorded at 126 and 134 DAS showed the per cent damage to be less and was only about one per cent. The damage was mainly caused by termites.

In vertisols during postrainy season the per cent damage by the borers was relatively low and it was about 1.81 per cent from the observations recorded in different varieties.

Regarding the pod borer incidence in different varieties sampled twice at 140 and 155 DAS, no variety was free from pod borer damage (Table 5). Most of the varieties had around 1 per cent damage except in ICGV 86599 and ICG(CG)S 49 where the damage was 3.43 and 9.80 per cent respectively. Interestingly, in these two varieties the damage was due to earwig only. In all the remaining varieties the damage was equally due to earwig and *Spodoptera*.

4.4 NATURE OF DAMAGE

As the damage is not usually detected until the crop is harvested, it is not always easy to determine which insect caused the damage, especially when the pods are rotting. Nevertheless an attempt has been made to characterize the symptoms of damage associated with each pod borer pest.

Table 4. Groundnut pod borer infestation in alfisols and vertisols during rainy season 1991 at ICRISAT Center.

Soil type	Age of crop (days)	No. pods observed	No. pods damaged	(%) damage	Relative % damage by different pod borers	
Alfisols RUS 6B	90	2587	35	1.35	Earwig	- 77
					Termite	- 23
	97	1820	37	2.03	Earwig	- 81
					White grub	- 13.5
					Termite	- 5.5
	104	2703	50	1.85	Earwig	- 84
					Termite	- 10
					Others	- 6
	111	1397	39	2.79	Earwig	- 74
					Termite	- 26
	117	2125	31	1.46	Earwig	- 61
					Termite	- 35
					White grub	- 4
	121	1677	29	1.73	Earwig	- 62
					Termite	- 38
	128	1199	20	1.66	Earwig	- 55
					Termite	- 45
Vertisols BUS 1C & 1B	73	2873	63	2.19	Earwig	- 100
	85	935	63	6.73	Earwig	- 90
					Wireworm	- 10
	93	1035	62	5.99	Earwig	- 86
					Wireworm	- 14
	100	892	61	6.83	Earwig	- 87
					Wireworm	- 13
	105	1023	71	6.94	Earwig	- 85
					Wireworm	- 15
	112	844	56	6.64	Earwig	- 86
					Wireworm	- 14
	125	863	228	26.14	Earwig	- 83
					Wireworm	- 17

Table 5. Pod borer infestation in different groundnut varieties grown in vertisols and alfisols during postrainy season, 1991-92 at ICRISAT Center.

Soil type	Age of crop (days)	No. pods observed	No. pods damaged	(%) damage	Relative % damage by different pod borers
Vertisols					
ICGV 86599	140	673	6	0.89	Earwig - 100
	155	1079	37	3.43	
ICGS 65	140	543	5	0.92	Earwig - 50
	144	420	5	1.19	*Spodoptera* - 50
ICGS 11	140	498	10	2.01	Earwig - 50
	145	305	2	0.66	*Spodoptera* - 50
ICGS 44	140	675	11	1.63	Earwig - 50
	144	452	7	0.88	*Spodoptera* - 50
ICGS 76	140	408	0	0.00	Earwig - 50
	155	327	3	0.92	*Spodoptera* - 50
ICG 2271	140	165	1	0.61	Earwig - 50
	155	193	1	0.52	*Spodoptera* - 50
ICG(CG)S 49	140	204	20	9.80	Earwig - 100
	155	273	13	4.76	
ICG(FDRS) 10	140	560	5	0.89	Earwig - 50
	155	736	11	1.49	*Spodoptera* - 50
ICGS 37	140	436	4	0.92	Earwig - 50
	155	525	4	0.76	*Spodoptera* - 50
Alfisols					
ICGS 44	126	2124	4	0.99	Termites - 100
	134	2318	4	1.04	"

4.4.1 Earwig

Based on the field as well as laboratory observations, the type of pods preferred, position of damage, size, shape, and number of holes, nature of damage to pod and kernel made by the earwig have been described in detail. Attempt was also made on the time and duration of feeding. Based on the structure of faecal pellets, the earwig damage has also been distinguished from the rest of the pod borers.

4.4.1.1 Pod Preference

Maximum damage was seen in the tender developing pods rather than in the mature pods. Such pods show a soft venation, which would not have hardened yet. The kernels in such pods are whitish pink and soft, surrounded by white juicy pod flesh. In very few instances was a properly filled kernel bored into. Even in such cases, kernel was not fully bored into. It was found that bored pods obtained from both the red and black soils showed similar symptoms of damage.

4.4.1.2 Position of Bore Holes

Pods infested with earwigs were mostly with one hole per pod, but it was not uncommon to find two or three holes on a single pod. Location of the holes were mostly observed on four regions of the pod, a) area around dorsum of the beak (Fig. 1a), b) nearer to the incurved area of the beak (Fig. 1b), c) on the dorsal side at the constriction between two kernels (Fig. 1c), and d) also nearer to the base of the pod (Fig. 1d). The preference for boring appears to be the area around the beak mostly on the dorsal side followed by the ventral side (preference for this area was around 80 per cent).

4.4.1.3 <u>Size of the Holes</u>

The holes generally measured 1-3 mm. Sometimes bigger holes of 4-5 mm were observed. The size of the hole perhaps depends upon the stage of the earwig boring into the pod. Both nymphs and adults of earwig were found to bore the pod.

4.4.1.4 <u>Shape of the Holes</u>

To the naked eye the hole made by a earwig looks regularly round or oval, the first being prevalent in most cases. On close examination under a microscope, the edges of the hole appear irregular and the hole appeared irregularly oval or triangular.

In most observations the holes bored by earwigs were clear without any plugging with soil, frass, or excreta. Very few holes were found plugged with soil.

4.4.1.5 <u>Nature of Pod Damage</u>

Laboratory observations on the nature of pod damage by earwig revealed that it first makes a hole through the shell of the pod, followed by scraping through the pod flesh, making a pathway towards the kernel. The pathway is not straight, but often wavy and erratic. When freshly done the pathway appears yellowish

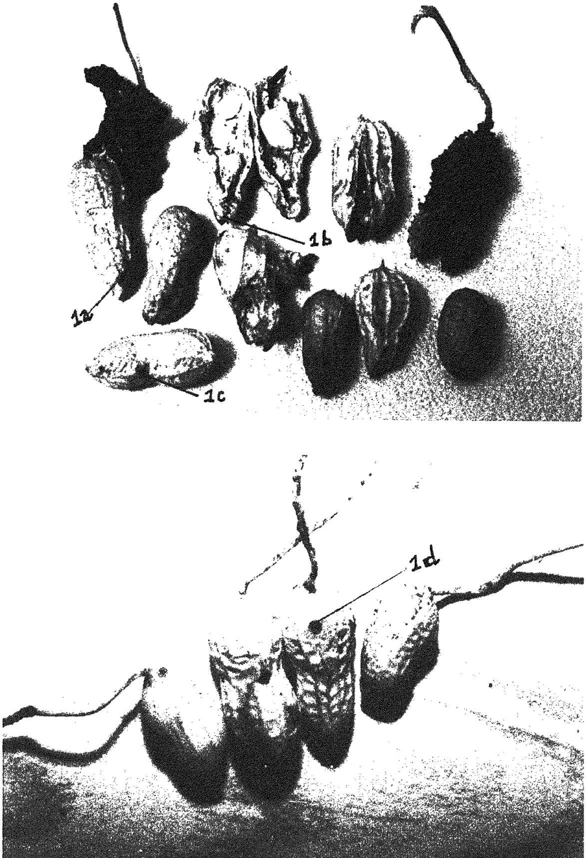


Figure 1. Bore holes due to earwig in groundnut pods.
a) Around dorsum of beak; b) Nearer to incurved area of beak; c) On the dorsal constriction; d) Base of pod.

orange due to the feeding against the white succulent flesh in young tender pods. The pathways in the pod were mostly found to lead to the kernel, but occasionally 2-3 pathways were also seen in the endocarp with 1-3 holes reaching up to shell. However, no external hole on the shell was visible from outside, indicating that once it enters, it may not come out through any other hole other than the entry hole. As a result, the white papery coat in slightly matured pod is torn showing the progress of the earwig through the pod flesh. In the course of time these yellowish pathways turn black and stand out distinctly in the white flesh. The pathways generally start at the periphery or boundaries of the split pod (Fig. 2a) and proceed towards the centre. When the pods are slightly old the damage appears as wooly shreds of dried pod material.

4.4.1.6 Damage to Kernel

Depending on the suitability of the kernels, one or both kernels of the pod are damaged by earwigs. Suitability refers to the stage of development of the kernel. The earwig seems to prefer very young and tender kernels, when the coat or testa color is whitish or whitish pink. When two kernels, one immature and the other slightly harder and bigger are present, the earwig prefers the first one. This sort of situation was seen where the hole was made in the beak (Fig. 3a). But this preference is not a steadfast rule, because in cases where the earwigs bore from the top, it consumes the kernel it encounters first and proceeded serially.

4.4.1.7 <u>Number of Holes on the Kernel</u>

As per the feeding habit of the earwigs, they were found to bore into the kernel at 2 or 3 places, but never with a single hole. What was found in the end (after devouring) was the testa with 2 or 3 holes in it. Wherever two holes were observed, one was the entry hole and the other was exit hole. Wherever nibbling was observed it looked like a cavity rather than a single hole (Fig. 4). Mostly the seed was totally consumed, leaving only the testa and many times a thin kernel tissue left underneath the testa. This is a definite character of identification of the earwig damage. Rarely the earwigs were found to have devoured the kernels voraciously with no signs of regular holes, leaving only a remnant of the kernel.

Regarding the typical feeding behaviour of the earwig, the ultimate destination appeared to be the embryo. Depending on the position of the entry into the pod, the hole on the kernel varied. Sometimes the hole in the kernel was seen at the tip of the kernel facing the hole on the pod. In some instances the earwig made a pathway from the entrance hole on the pod from underneath the kernel and bored into the kernel from the side.

The entrance hole in all cases was usually roundly triangular (Fig..2b) and is always smaller than the exit hole. The entry hole measures 1-3 mm, but the exit hole is about 5-6 mm. In most cases the hole at the rear end (exit hole) was irregular and it appeared with ragged edges like a cut made by a saw (Fig. 3b). The earwig scraped the flesh of the kernel on its way to the embryo. In this manner the kernel was totally consumed leaving only the testa. In some cases the kernels were observed with traces of mud and scraped off material of the kernel. Both the entry as well as the exit holes on the kernel were tainted orange. When the earwig made some unsuccessful attempts at boring into the kernel, even these were indicated as orange markings on the kernel. These were not seen when the kernel was mechanically damaged by pinching.

In some of the earwig damaged pods, certain white mites were also observed on the remnants of the kernel.

4.4.1.8 Excreta

To identify the earwig damage through differences in the structure of faecal matter, an attempt was made to observe the excreta content in bored pods. It was observed that the pod flesh as well as the kernel were littered with pellets of reddish brown or black excreta (Fig. 5). When freshly excreted, the pellets were cream coloured, which turn to reddish brown and later black. In the laboratory, when an earwig was left in an empty 7.5 cm plastic cup it was observed that the pellets were surrounded by a layer of liquid which dried up and formed a stain in the cup. This may not be clearly visible in a pod as it may merge with the background. When the bored pods were opened, a long time after the actual boring, the black pellets may not be as clear and distinct. They may appear as soil particles. These pellets were woven together by fungal mycelia or webs made by mites. The shape of the pellets of excreta were cylindrical with constrictions (3 segmented,

Figure 2a Pathway made by earwig at the periphery of the split pod

Figure 2b Roundly triangular entry hole on kernel

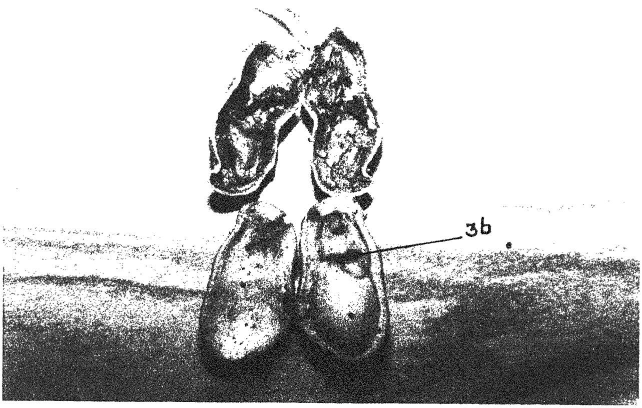


Figure 3a Earwig's preference for immature kernels

Figure 3b Irregular exit hole on kernel (with ragged edges)

Figure 4. Nibbling on the kernel by earwig.

Figure 5. Pod flesh and kernel littered with faecal matter of earwig.

These can clearly be observed under a microscope. The excreta can take other irregular forms, but most often the pellet was the most common. The pellets have been found all over the feeding or bored area of the kernel and pod.

4.4.1.9 Time of Feeding

In the laboratory, it was found that there was no specific time for feeding. Sometimes, the earwig stayed on top of the pod, when not feeding. When it enters the pod, it stayed inside the pod until it was disturbed. It was observed in one instance where the earwig entered the pod in the morning at 0900 hrs and did not come out even after 1700 hrs in the evening. It can be said that the feeding process was more or less continuous though the possibility of the earwig taking shelter was not ruled out.

4.4.2 Termite

Termite damage was observed mostly on the developed (mature) pods, whereas tender developing pods were not attacked. The symptom of attack by the termites was primarily pod scarification with occasional bore holes.

4.4.2.1 Size and Shape of Holes

The size and shape of the holes made by a termite show a wide variation. As far as the size is concerned, the holes measured from 1 to 6 mm and at the extreme to 1.5 or 2 cm. The shape varies from round to oval or irregular. The holes were mostly seen at the beak region and also at the constriction. The hole may show irregularly cut ends or may appear perfectly round. Some pods show scarification indicating the action of termites.

4.4.2.2 Damage to Kernel

In the majority of instances (99 per cent), the kernels were totally consumed leaving no remnants. The endocarp of the pod was totally scraped away leaving only the outer shell with the fine reticulation left on the inner side of the pod.

A unique practice of the termites was to fill the attacked pod with the surrounding soil (Fig. 6). This acted as a certain diagnostic feature for identification of termite damage to pods. The pod was usually packed with the mud particles both in alfisols and vertisols, but in sandy soils, it was observed that the sand poured out of the holes leaving the pod empty. Only one per cent of kernels were coated with mud and the endocarp was totally consumed leaving the kernels untouched.

4.4.3 Wireworm

Two species of wireworms were collected during sampling at ICRISAT as well as the survey trip. From the pods damaged by these insects the symptoms of damage can be outlined as follows: a) The wireworms have caused damage to both developing and almost mature pods. Among the 2 species, the brown coloured one showed preference to the pods nearing maturity. The wireworms also preferred the area around the beak to enter the pod (Fig. 7). The holes were 3-4 mm in diameter depending on the size of the wireworm. The holes are oval to round in shape (Fig. 8a). The edges of the hole were irregular and sometimes one end of the hole was thickened. This species seemed to prefer wide pods as compared to narrow ones. Both the kernels as well as the endocarp were found to be damaged by this wireworm. When the kernels were very tender, the wireworms relished the endocarp more than the kernels. The kernels showed signs of nibbling reflected by the yellowish orange markings on the kernel. But it has been observed that half matured kernels were consumed voraciously with no signs of holes or any remnants of the kernel, except the rim of the shell the entire endocarp was eaten away. When freshly eaten the inner side of the pod appeared yellowish. As time passed the same appeared as blackened frass (Fig. 8b).

b) The second species of wireworm (white coloured) was distinctly different from the first one by the hole it made on the pod. The hole was no doubt mostly located at the beak, but the position varied. In this species, the hole was made just below the beak as against the side of the beak in the former one. The holes measured 3-4 mm and the holes appeared oval in shape or more like an incision with the length more than the breadth (Fig. 9). The hole was also peculiar in that the area surrounding the hole was scraped away to form a sort of a border demarking it from the rest of the pod. It was found to feed both on the kernel as well as endocarp. Both the species of wireworms did not make pathways but systematically consumed the pod flesh, starting from one end to the other and the

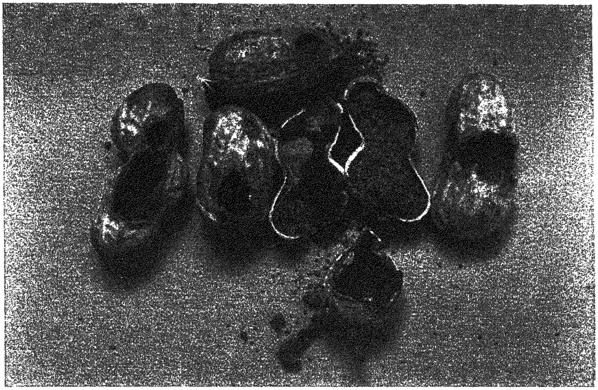


Figure 6 Termite damaged pods filled with soil

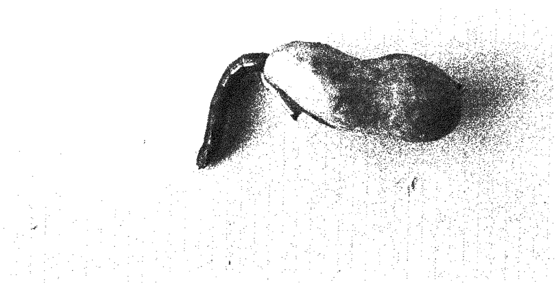


Figure 7 Brown coloured wireworm boring into the pod at the beak

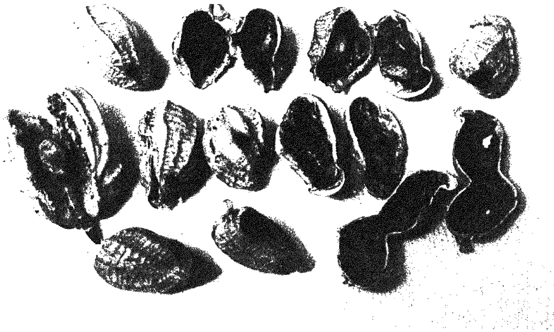


Figure 8a. Round to oval holes made by brown wireworm.

Figure 8b. Blackened frass like material left in the pod.

Figure 9. The bore hole more like an incision made by the white coloured wireworm.

pods were filled with blackened frass. Specific holes of 1-2 mm were found in the kernels of the pods attacked by the white coloured species of the wireworms. The location of holes was not specific, but in many instances at the tip of the kernel or at the ridge between the cotyledons (Fig. 10). The kernels showed irregular nibbling or sometimes were consumed as whole.

4.4.4 *Spodoptera*:

Spodoptera litura hitherto a voracious foliage feeder was found feeding on the groundnut pods, mainly in the postrainy season in sandy soils of coastal Andhra Pradesh. Considerable number of pods were found damaged by this pest. The damage of *Spodoptera* on casual examination may be mistaken for the damage by any coleopteran larvae. However, certain distinguishing features of damage due to *Spodoptera* were observed.

a) The beak was the vulnerable area where a large gaping hole was visible. In some cases a hole measuring 5 mm to 1 cm was observed at the beak or the area around the beak. b) Empty pods with a hole at one end or both ends were a common sight (Fig. 11). c) The hole on the pod was typical in being apple-shaped with protrusions in the middle. d) In some instances, the pod has been found to be chewed off leaving a round gaping hole at the bottom. e) Mature pods were most preferred. f) It was found that the larva was feeding on both the kernels and the endocarp. Unlike some of the other pod borers *Spodoptera* first devours the kernels which are moderately or well filled and then scrapes off the endocarp

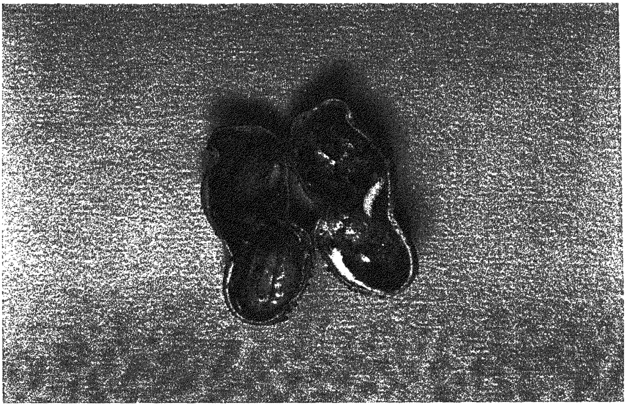


Figure 10. Kernel damage by white coloured species of wireworm

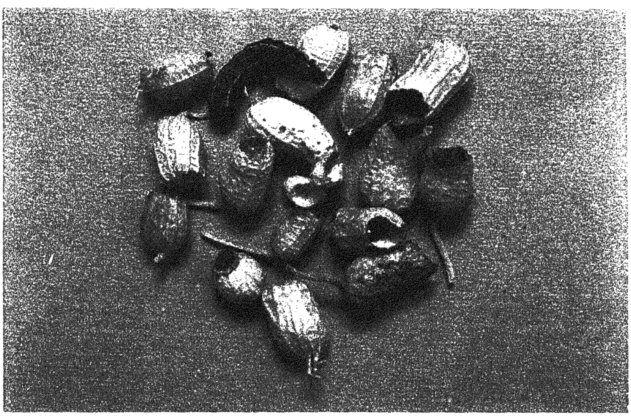


Figure 11. Apple shaped hole at beak made by Spodoptera litura.

leaving the bore shell with the venation distinctly standing out. g) No frass is left in the pod. The excreta was also not seen since it would be mixed up with the soil or decomposed.

4.4.5 White Grub and Curculionid Grub

Two coleopterans, white grub and curculionid grub were found damaging groundnut pods. The damage appeared mostly in the form of large portions of pods being eaten away by these grubs. The typical symptom was the presence of irregularly chewed ends of groundnut pods (Fig. 12). In fact, no definite shape or size can be assigned to the hole. The pod was chewed out at one or sometimes both the ends. Most of the time this type of damage is seen in pods nearing maturity where the endocarp is used up by the developing kernel. Mostly the common sight is the presence of the papery white layer sticking to the shell. The kernels were totally consumed leaving the shell alone. The presence of mud or any other material was not observed.

4.4.6 Subterranean Ant

At the time of harvest in the ICRISAT fields, pods with very minute holes were found associated with red ants. The holes measured 0.5-1.0 mm (pin tip size) (Fig. 13a). It was observed that in most cases these holes (tunnelling) did not run deep and were limited to the shell and its tissue. Internally, in most cases, no injury could be seen in the kernel, but occasionally the kernel and its flesh was found to be irregularly eaten (Fig. 13b).

Figure 12. White grub damaged pods.

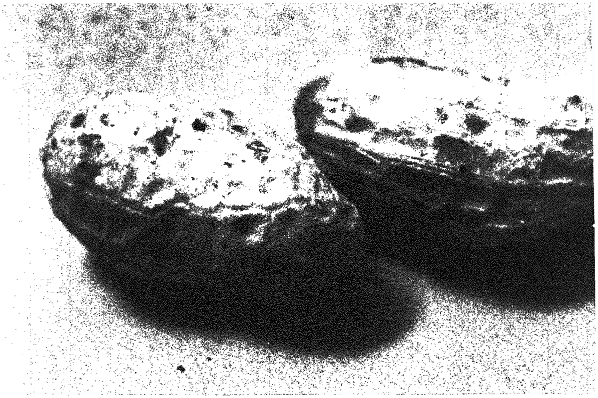


Figure 13a. Pin tip holes made by subterranean ant.

Figure 13b. Irregular kernel damage by subterranean ant.

4.5 KEY FOR IDENTIFICATION OF GROUNDNUT POD BORERS

Based on the pod injury, nature and position of the hole, type of kernel damage, and excretal structure, a key has been formulated for the identification of pod borer involved. Only the pod borers recorded in the present investigation viz., earwigs, termites, white grubs, wireworms, subterranean ants, and *Spodoptera* were considered for the formation of key (Table 6).

4.5.1 Earwigs

It is evident from these findings that earwigs attack immature pods with 1-3 mm holes on all sides of the pod. The kernel showed 1-2 mm entry and exit holes littered with 3 segmented cylindrical excreta.

Two types of termite damage (scarification and pod boring) was noticed. In case of pod boring the termites caused irregular pod damage and the pod cavity filled with soil particles was the typical character.

4.5.3 Wireworms

Wireworms made 3-4 mm oblong or oval holes on the ventral side of the pod surface close to the beak region. The wireworm damaged pods normally developed blackened internal pod wall. During the study period very few specimens of wireworms were found. Hence characterization of damaged symptoms was not very clear.

4.5.4 White grubs

Irregular feeding on pods with no sign of frass or soil inside was commonly seen in white grub damage.

4.5.5 *Spodoptera litura*

Four mm regular apple shaped holes on the beak end of the pod was common and the pod cavity was not filled with frass or soil.

4.5.6 Subterranean ants

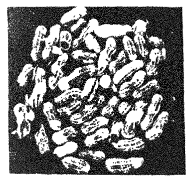
These are known to cause several 0.5-1 mm superficial tiny holes on the matured pods, along with irregular feeding on the kernel leaving some frass.

Table 6. Key to identify different groundnut pod feeders (based on damage symptoms)

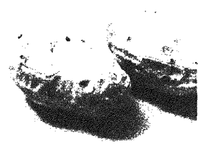
1. External pod injury on matured pods 2

... External and internal pod injury on both matured and developing pods 3

2. Pod scarification in the absence of superficial tiny holes 4



... Several superficial tiny holes on pods 5



3. Pod damage with irregular holes 4

... Pod damage with regular uniform holes 5

4. Irregular feeding on any part of the pod with no sign of frass or soil . . . . . WHITE GRUBS

... Irregular feeding on any part of the pod with pod cavity filled with soil particles . . . . . TERMITES

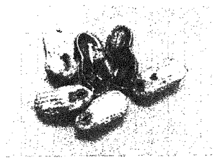
5. 0.5-3 mm round holes on dorsal, ventral or lateral sides on tender and maturing pods 6

... >3 mm holes other than round shape on pods nearing maturity 7

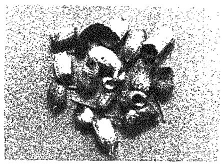
6. 0.5-1 mm minute perforations on the lateral sides of the matured pods with irregular feeding on kernel with frass . . . SUBTERRANEAN ANTS

... 1-3 mm holes on dorsal and ventral side of the pod at the beak and constriction on tender pods, remnants of kernel with 1-2 mm entry and exit holes littered with 3 segmented cylindrical excreta . . . . EARWIGS

7. 3-4 mm oblong or oval shaped holes on the ventral side of the pod at the beak with blackened internal pod wall . . . . . . WIREWORMS



... >4 mm apple shaped holes mostly at the beak no frass or soil . . . SPODOPTERA LITURA



DISCUSSION

CHAPTER V

DISCUSSION

5.1 GROUNDNUT POD BORERS

A wide range of pod borers have been reported from different parts of the world on groundnut viz., the earwigs, *Euborellia stali* (Cherian and Basheer, 1940), *E. annulipes* (Das and Ray, 1988), *Anisolabis* sp (Melamed Madjar and Sholomo 1970), and *Labidura bengalensis* (Singh *et al.* 1990); termites, *Microtermes lepidus* (Johnson and Gumel 1981), *Odontotermes brunneus* (Reddy and Samnaih, 1988); Wireworms, *Heteroderes* sp, *Cebria* sp (Bass and Arant 1973), *Prosephus* sp, *Pseudorophoeus protensus*, *Cardiophorus* sp and *Dyakus* sp (Wightman 1989); false wireworms *Gonocephalum* spp (Wightman and Amin, 1988; Wightman *et al.*, 1990); chrysomelids, *Diabrotica undecimpunctata howardi* (Fink 1916), *D. balteata* (Bass and Arant 1973) and *D. speciosa* (Lorencuoa *et al.* 1982); white grubs, *Strigoderma arboricola* (Bass and Arant 1973), *Lachnosterna consanguinea*, *L. serrata* and *Maladera* sp (Wightman *et al.* 1990). In addition millipedes, *Peridontopyge rubescens* and *Syndesmogenus mimeuri* (Masses 1983), *P. spinosissima*, *P. perplicata* (Appert 1960), subterranean ant - *Dorylus orientalis* (Roonwal 1975, ICRISAT 1987, Singh *et al.* 1990), *Spodoptera litura* (Wightman and Amin, 1988) and *Etiella zinckenella* (Das and Ray 1988) were also found boring on groundnut pods.

In the present investigations, the earwigs, *Euborellia annulipes, E. plebeja* and *Forcipula quadrispinosa*, subterra-nean ant *Dorylus labiatus*, the white grub *Holotrichia consanguinea*, lepidopterous defoliator *Spodoptera litura*, termite *Odontotermes wallonensis* and the unidentified species of wireworms have been recorded in the surveys as well as at ICRISAT Center (Table 2). For the first time two new species of earwigs *E. plebeja* and *Forcipula quadrispinosa* and the subterranean ant *Dorylus labiatus* have been observed as pod borers of groundnut.

Euborellia stali, a cosmopolitan insect was reported from several locations like Coimbatore and South Arcot districts of Tamil Nadu (Cherian and Basheer, 1940), Karachi, Pondicherry and Bombay (Burr, 1910), *E. annulipes* from the north eastern states of Manipur and Tripura (Barwal and Gupta 1991, Das and Ray 1988). At ICRISAT *Anisolabis annulipes* was the commonest species. *Euborellia* and *Anisolabis* were synonymous (Smith and Barfield, 1982). The present study also revealed that earwigs are predominant among pod borers of groundnut. Next to earwigs, termites have been often found associated with bored groundnut pods. All other pod borers were less important compared to earwigs and termites. The earwigs were the important pod borers in both alfisols and vertisols more so in the latter (Table 4). Wightman *et al.* (1990) also reported *A. annulipes* as the commonest in the vertisols. Earwig population was relatively high in rainy season than in post rainy season (Table 4). Though literature supporting the predominance of certain pests in certain regions is not available, an attempt has been made to account for the observations made above. Maxwell Lefroy (1971) stated that earwigs were most active in the rains and damp weather, being dependant on moderately damp conditions. In irrigated lands they are active throughout the year except when cold drives them to hibernation in the shelter, as happens in colder parts of the plains. Barwal and Gupta (1991) also indicated that high moisture is necessary for multiplication of earwigs. Taking these statements into consideration, the predominance of earwigs in the vertisols in the rainy season can be reasonably accounted. In general soil insects are more prevalent in moist conditions. The vertisols, due to their high moisture retentive capacity than alfisols, may provide an ideal condition for the multiplication and development of most soil insects, earwigs in particular. Many soil insects are attracted to carbondioxide (Co_2) which is released by decaying organic matter in the soil as well as by living plant roots (Villani and Wright, 1990). Both phytophagous and saprophagous insects may use Co_2 to locate food sources. Therefore, it may be possible, that the organically rich black soils, provides sufficient Co_2 to serve as an attractant to the earwigs.

Termites, *Microtermes lepidus* and *Odontotermes* were reported to cause losses to groundnut crop in the well drained sandy loam soils of the Sudan Savannah in Nigeria by Johnson and Gumel (1981). They also observed a significant relationship between rainfall and *Microtermes* damage, the former influencing the foraging behaviour of the termites. The same was reported by Wightman (1988) from Southern Africa where the termites assumed an important role as the soils became drier. The present observations also confirmed that termites prefer light soils (alfisols). Termites were found to cause maximum damage in dry conditions, particularly at the end of growing season (Wightman *et al.* 1990). A significant relationship was reported between the level of *Microtermes* damage and the annual rainfall. The distribution of the rainfall particularly towards the end of the growing season, was of primary importance. Investigations on the effect of rainfall on the surface foraging activity of *Microtermes*, showed that surface foraging was stimulated after heavy rain and sharply declined at the end of the wet season. It was thus observed that for a given population level highest levels of damage would occur in those locations with well drained soils and a short wet season (Johnson *et al.* 1981). This could probably explain pod boring activity of termites along with earwigs in the alfisols, these soils being reasonably well drained and the soil may not hold as much moisture as to deter termites from attacking the underground parts of the groundnut plant. The soil structure of the alfisols may facilitate easy movement and construction of galleries and tunnels when compared to the vertisols where with more moisture, the soil becomes cloggy and difficult to manipulate. Moreover, groundnut is generally grown in the lighter soils to a large extent, therefore, the termite menace in the vertisols may be of minor importance.

White grubs were most frequently found in the sandy soils or well tilled ferruginous loams, especially where rainfall was average or better than average. Wightman *et al.* (1990) observed white grubs in the red loams of Malawi, silts of Luangwa valley and light red soils near Chipata in Zambia. They also cited two species of white grubs *Lachnosterna consanguinea* in the light alluvial soils of northern India and *L. serrata* throughout the subcontinent to be prominent. At

ICRISAT Center pod damage by white grubs was observed only in alfisols (Table 4) in the rainy season. Amin (1988) also stated that white grubs were major pests in sandy loam or light red soils and not in clayey soils. Though no reason has been given for this soil preference, it may be assumed that the friable structure of the red soils may facilitate easy burrowing by the white grubs which may be rendered difficult in the more moist and sticky clayey soils. Usually a single generation is found, that too with the onset of rains, hence the occurrence of pest mostly in rainy season.

Very few specimens of wireworms and false wireworms found both in vertisols and alfisols during the surveys and also at ICRISAT Center, made it difficult to specify the predominance and soil preference of the pest. However, Wightman *et al.* (1990) observed the *Gonocephalum* spp to be the commonest in the vertisols of Malawi. The other pod borer, which caused considerable damage during post rainy season was *Spodoptera litura* which was more prevalent in the coastal sandy areas and the vertisols. Wightman *et al.* (1990) reported pod boring habit of this pest in the light soils of northern India. Probably the larva which is a nocturnal feeder, while taking shelter during day time near pod zone in the friable soil feeds on the pods. This explains the importance of this species as pod borers in the sandy soils. This can be seen in the case of a related species *Spodoptera frugiperda* where sandy-clay and clayed-sandsoils were found suitable for pupation and adult emergence (Garcia *et al.* 1987). The same report however states that the emergence is directly proportional to temperature, whereas with regard to humidity the reverse was true.

Regarding the subterranean ant, *Dorylus orientalis* was the species reported to perforate the groundnut pods in Sri Lanka (Fletcher 1914) and the soil preference has not been indicated. Even in Thailand this pest was found to cause considerable damage to the underground parts of the groundnut plants (Keerati Kasikorn *et al.*, 1984). As the report of *D. labiatus* is a new one, further observation is necessary to explain its incidence.

5.2 NATURE OF DAMAGE

There is every possibility of mistaking damage caused by one pod borer for another, since the damage is only seen but not the causal organism many a times. Unless the symptoms of damage are clearly defined for a particular pest it is difficult to pinpoint the causal organism. The earwig *E. stali* was observed to bore into tender pods (Cherian and Basheer 1940). This was also the case in Israel where *Anisolabis* damaged immature pods (Melamed-Madjar and Sholomo, 1970). Purushottaman *et al.*, (1970) however observed that damage was done at all stages of pod development. The results of the present study showed that tender and developing pods were the main targets probably due to the softness of tissue facilitating easy entry of the pest. In rare instances completely filled pods were attacked, and the kernel was partially damaged.

Quite often one hole was seen on the pod, which served as both entry and exit hole; sometimes more than one hole was also present, which might be due to the attack by more than one earwig at different times. The earlier studies on the damage done by earwig did not provide any details on these aspect. The preferred site of boring for the earwig, as in the case of other pod borers was the area around the beak. The reasons for this preference could be due to the tenderness of the beak as compared to the rest of the pod. The development of the pod proceeds downwards from the peg tip, the beak developing last, hence the tenderness and vulnerability near the beak (Ramanatha Rao, 1988). It was also observed that the bore holes were made between the ridges of the pod, probably to avoid the thick fibres which impedes the easy boring of the pod.

The damage caused by earwig has not been specified by the earlier workers. In the present investigation detailed obser-vations on the symptoms of damage by earwigs indicated 1-3 mm sized holes. The range in size may be attributed to the attack by different developmental stages of the earwig i.e., both nymphs and adults boring into the pods. The earwig slowly scrapes the intended spot with its mandibles making it deeper and deeper until a clear cut hole is formed. The hole may be enlarged to accommodate the rest of the body. The movement of the earwig in and out of the pod, also result in increase in size. The forceps of the earwig also aid in this process.

The holes on the pods were plugged with soil particles, excreta and discolored pulp in only a few cases and not in all cases as stated by Purushottaman *et al.* (1970). The plugging may possibly be done to prevent other insects from entering the pod or to avoid predation and also to serve as protection for the eggs when these are laid inside.

The damaged pods when split open, showed pathways starting from the rim of the pod to the kernel. The earwig may have to nibble through the fleshy endocarp to reach the kernels, resulting in the pathways. Even in the kernels the most preferred ones were tender kernels. Among the two kernels, the one at the beak end was most frequently attacked first. Studies on pod development revealed that the basal ovule is the first to form followed by the kernel at the beak end (Ramanatha Rao 1988). As the beak area was the most vulnerable point for the earwig to bore a hole, the kernel at this end would automatically be attacked first. In case of pods bored at the base of the pod, the basal kernel was damaged first irrespective of the maturity of the kernel. Thus these studies have indicated the most favoured spot of boring on the pod or kernel by the earwig.

Though the pod generally showed one hole only, the damage to the kernel was characterized by two holes - an entry and an exit hole. The entry hole was smaller and regular than exit hole. The earwig feeds on the contents of the kernel by slowly nibbling the material leading to the embryo. During this process, the earwig having a flexible body accommodates itself in the kernel by assuming a curved position. By the movements of earwig it may be possible that the rear end of the kernel was cut through by the mandibles as well as the forceps. The position of the entrance hole can be attributed to the convenience of feeding of the earwig. The holes on the lateral side of the kernel in some cases may be due to more tender flesh which facilitates easy penetration and also a shorter route to the embryo (Fig. 2).

The kernel showed orange discoloration at feeding site, which was not seen when the kernel was mechanically damaged. Probably this discoloration was due to chemicals associated with the saliva during earwig feeding. Another factor by which earwig damage could be identified is the presence and nature of excreta, which was used for the first time in the present investigation to identify the earwig damage from the rest of the pod borers. The cylindrical three segmented pellets were typical to the earwig. The mites of the Fam. Aschidae were found associated with the earwig damaged pods. The webbing of the excretal pellets may be due to these mites or fungal mycelia.

The termites in keeping with their tradition of feeding on sound or decaying wood or any cellulose containing material (Richard and Davies, 1977), scarify the groundnut pods. In addition, they also bored pods and consumed the pod tissue and kernels. Termite attack was mostly confined to mature pods, increasing in infestation with the delay in harvesting (Wightman *et al.* 1990). The tender pods were not attacked as they prefer the woody or corky part of groundnut (McDonald and Harkness 1963). Johnson *et al.* (1981) observed small rounded 1 mm holes behind the beak caused by *Microtermes* spp in Nigeria. Contrary to this in the present study it was observed that the size of the holes ranged between 1-6 mm and sometimes 2 cm. The shape was not always round, sometimes the pod was irregularly chewed away. This probably explains the range in the size. Here again the beak was the preferred spot for boring (Fig. 6). The bored hole along with the pod scarification would implicate the termites as the causal organism. As reported by Johnson *et al.* (1981) the termites, after consuming the internal contents replace it with soil. Thus, this character of pod filling with soil is unique to the termites alone. Termites are known to construct covered passageways of earth or fecal matter which enable them to work concealed from the light and enemies, while surrounded by the requisite humidity (Richard and Davies 1977).

Wireworms and false wireworms were reported to bore through the shell and devour the seeds (Wightman *et al.* 1990). But the size and shape of the hole was not specified. Of the two unidentified wireworms, found in the present investigation the brown coloured one made oval holes with a thickening at one end. This might be the result of friction generated by the movement of the pencil shaped wireworm in and out of the pod. The size of the hole was 3-4 mm in both cases and varied with the width of the insect. The broader pods may be preferred to accommodate the long body of the wireworm while consuming the kernel. The damage by this pest can be distinguished by the presence of blackened sheds of tissue and frass left behind after eating away the kernels. Most of the time, the beak was the vulnerable point for boring. Its preference for mature kernels, shows its potential to cause losses at the later stages of crop growth. The white coloured species produced distinctly different damage symptoms by making oblong holes with the surrounding area scraped away to form a distinct border around the hole. It also consumed both endocarp and kernels.

In case of white grub and curculionid grub the pods nearing maturity were irregularly chewed away at the beak end and the kernels were consumed. Wightman *et al.* (1990) reported that they destroy pods at all stages of development and another report by Johnson *et al.* (1981) states that larvae of *Schizonycha africana* made no distinct entry hole into the pod, but consumed large parts of the pod. In the present observations also no specific holes were found. No signs of excreta or soil were found.

In the case of damage caused by the subterranean ant Wightman (1989) reported 3 mm holes on the pod made by *Dorylus* spp. which also removed the seeds from the pod. In the ICRISAT alfisols, pods with several fine holes of 0.5-1 mm diameter were observed. These holes were limited to the shell alone and did not penetrate deeper to seed zone in most cases, but occasionally damage upto kernel was also noticed where unlike termites, no soil was found in the pods. But soil filling was reported in Thailand (Thailand Coordinated Groundnut Improvement Program Progress Report 1986).

The polyphagous defoliator *Spodoptera litura*, was occasionally found to feed on pods particularly in lighter soils. According to Wightman *et al.* (1990) it may probably follow the peg while resting during the day and end up damaging the pods. It was found that *Spodoptera* damaged pods had chewed out ends like the coleopteran damage. But the character which distinguished damage by this insect was the presence of apple shaped hole near the base and beak of the pod. Prior to this no report describing the nature of damage by *Spodoptera* was available. The *Spodoptera* larva may first feed on one side i.e., one hemisphere and then start from the other side giving rise to the two protrusions in the middle and thus the apple shaped hole.

Though report on the nature of damage by individual pests has been given for few pod borers of groundnut so far, a key to identify different pod borers based on the damage symptoms was not available. Hence an attempt has been made with a hope that key would provide a clear cut means of identifying the pod borer concerned by seeing the nature of damage. However, in some cases like damage by the false wireworms and wireworms, further investigations may be needed to clarify any ambiguity. Similarly the characterization of the damage symptoms due to pod borers like *Diabrotica* spp., *Etiella zinckenella* and millipede may also help in developing broad based key for all the recorded groundnut pod borers. So also studies on the biology, population dynamics in soil types, host range, and economic importance would help in formulating management practices for this complex of insects.

SUMMARY

CHAPTER VI

SUMMARY

Investigations were carried out on the groundnut pod borers to identify the various species involved, determine the pest status and characterize the symptoms of damage by each pod borer pest. Studies were undertaken during the rainy and postrainy seasons of 1991/92 in the vertisols and alfisols at ICRISAT Center. In addition to observations at ICRISAT Center some of the groundnut growing areas of south India were also surveyed to understand the distribution and extent of damage by the groundnut pod borers.

The surveys as well as intensive search at ICRISAT Center indicated earwigs, termites, wireworms, subterranean ants, tobacco caterpillars, white grubs and curculionid grubs as important groundnut pod feeding insects. Earwigs were identified as the most predominant among the pod borers. The earwig species involved were *Euborellia annulipes, E. plebeja, Forcipula quadrispinosa.* The last two species are being reported as pod borers of groundnut for the first time. Other species identified as pod borers were the white grub (*Lachnosterna* (*Holotrichia*) *consanguinea*), termite (*Odontotermes wallonensis*), *Spodoptera litura*, wireworms (unidentified) and to a lesser extent the subterranean ant *Dorylus labiatus.*

Earwigs were observed both in vertisols and alfisols but more so in the vertisols at ICRISAT Center. Termites, white grubs, subterranean ants and *S. litura*

were found only in alfisols, particularly *S. litura* being more serious in the coastal sands.

The surveys for pod borer incidence irrespective of extent of damage indicated that 52 per cent of farmers' fields had infestation out of which 20 per cent of the fields had about 5 per cent damage and 6 per cent of fields had around 10 per cent damage. However, 26 per cent of fields had negligible damage (<1%). At ICRISAT Center the pod borer incidence ranged between 1.35-2.79 per cent in the alfisols and 6-25 per cent in the vertisols in the rainy season. It was also found that pod borer damage was more in the rainy season than postrainy season.

No preference was observed by the pod borers for the ten different groundnut genotypes. However, young developing pods were more preferred by earwigs whereas termites preferred mature pods.

Laboratory observations on the pod damage symptoms by earwig indicated its preference for immature pods. 1-3 mm round or oval holes on the dorsal side of the beak, a small round to triangular entry hole, a slightly bigger exit hole on the kernel and pod littered with three segmented faecal pellets with plugging of the hole were the characteristic symptoms. It was also observed that the excreta was often found with fungal mycelia or webs probably made by mites.

Termite damage was often accompanied by pod scarification with irregular feeding damage (1-6 mm) at beak and also at constriction. Most instances, termites completely devoured the kernels, endocarp leaving thin shell. All termite-attacked pods were invariably filled with soil particles.

Among the two unidentified wireworm species, the white coloured species made oval shape hole like an incision with the length more than the width. The hole was demarcated with a distinct scraping probably due to wireworms. The brown coloured species made 3-4 mm oval holes with a distinct thickening at one end.

The damage of white grubs and curculionid grubs was associated with irregular chewing of pod with no specific holes. Whereas larvae of *Spodoptera litura* made clear apple shaped holes. The damaged pods in all these cases were neither associated with soil plugging nor left with any frass.

The pods attacked by subterranean ants possessed several superficial pin holes all over the pod and kernel had irregular feeding damage with frass.

Based on the characteristic symptoms of damage of each pod borer pest, a key has been developed for the easy identification of different pod feeders.

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LITERATURE CITED

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