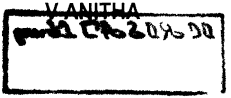
APPLIED ECOLOGY OF WHITE GRUBS IN GROUNDNUT IN ANDHRA PRADESH

By

V ANITHA



THESIS SUBMITTED TO THE
ACHARYA N G RANGA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENT
FOR THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY
IN THE FACULTY OF AGRICULTURE

DEPARTMENT OF ENTOMOLOGY
COLLEGE OF AGRICULTURE
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MAY, 1997

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ACKNOWLEDGEMENTS

I have no words to express my profound gratitude to Dr. D D R Reddy, Senior Scientist and University Head, department of Entomology, Agricultural Research Station, Amberpet, 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. J A Wightman, Principal Entomologist, Crop Protection Division, ICRISAT, for his close monitoring, timely suggestions and expert guidance throughout my research work.

I am also thankful to Dr. GV Ranga Rao, Entomologist, Crop Protection Division, ICRISAT, for the help rendered by him in completing the objectives of this project.

I am highly indebted to Dr. T B Gour, Associate Professor, Dept. of Entomology, for his critical observation and comments which helped to improve this piece of work.

I express my sincere thanks to Dr. Y N Reddy (Professor and University Head, Department of Horticulture) and Dr. Rajaram Reddy (Associate Professor, Dept. of Plant Pathology) for their valuable suggestions during the period of my study. I acknowledge with gratitude the help provided by Dr. T. Ramesh Babu, and Mr. Narasimha Reddy of the pesticide residue lab (AICRP [Pesticide]

I am grateful to the staff of Dept. of Entomology, College of Agriculture, ANGRAU, Rajendranagar, Hyderabad for their unstinted cooperation.

I appreciate the assistance and cooperation extended to me by all the staff of (Ex) Legumes Entomology unit throughout my research work at ICRISAT.

I deem it my privilege to thank Dr. B Diwakar, Program Leader, Training and Fellowships Program, ICRISAT, for permitting me to avail the research facilities at ICRISAT.

I am highly indebted to Mr. V Rameshwar Rao, Research Associate, CPD for his endless support and encouragement throughout my study period.

My thanks are also due to CSIR for granting the senior fellowship during the course of my research work.

Last but not the least, I take great pleasure in acknowledging the support extended by my family and friends in completing this work.

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DECLARATION

I, Ms. V.Anitha, hereby declare that this thesis entitled **"APPLIED ECOLOGY OF WHITE GRUBS IN GROUNDNUT IN ANDHRA PRADESH"** submitted to Acharya N.G Ranga Agricultural University, Hyderabad for the degree of **DOCTOR OF PHILOPSOPHY** is the result of original research work done by me. I also declare that the material contained in this thesis has not been published earlier.

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Year of submission	:	1997

Abstract

Investigations undertaken on the applied ecology of white grubs associated with groundnut through field collections by surveys of major groundnut growing tracts of Andhra Pradesh and under laboratory conditions at ICRISAT Asia Centre during 1995 and 96 seasons revealed that *Holotrichia reynaudi* Blanchard is the principal root grub species associated with groundnut. All the grubs collected from the root grub endemic areas of major groundnut growing areas of Andhra Pradesh viz., Ananthapur, Kurnool, Chittoor and Mahboobnagar, reared into adults resulted in only one species i.e. *H. reynaudi*. Adult collections from these tracts, identified based on the male genitalia and adult characters, in addition to *H. reynaudi* yielded few other melolonthids viz., *H. serrata, H. rufoflava, Schizonycha ruficollis, S. deciptens* and *S. fuscescens*. Adults of *H. reynaudi* were found feeding mainly on ber and also acacia whereas *H. serrata* preferred neem only . The life history of *H. reynaudi*, the principal white grub species of groundnut, was found to be similar to *H. insularis*.

Field studies conducted in the specially designed microplots at ICRISAT Asia centre on the seed treatment of groundnut, for the management of root grubs with chlorpyriphos and imidacloprid during the rainy seasons of 1995 and 96 indicated that chlorpyriphos 20EC is effective as a seed dressing chemical at 6 ml kg^{-1} seed against *H. serrata* grubs. In addition to mortality of the grubs, which lasted upto 40 days after release of the grubs, the mortality of the plants was negligible and the weight gain was less. Seed pelleting developed using gum arabic (100 ml of 27% gum arabic kg^{-1} seed) as sticker, chlorpyriphos 20EC (@ 6 ml kg^{-1} seed) and fine gypsum (80 , 120 g kg-1) as binding material prevented testa damage, was relatively more long lasting, caused highest mortality of grubs. Larval weight gain was also less resulting in higher pod yield per plot. Imidacloprid applied as a seed dressing chemical @ 5 g and 10 g kg^{-1} seed was also found to be equally effective as chlorpyriphos preventing plant damage and recording negative larval weight gain indicating antifeedant action. Chlorpyriphos residues were found both in the soil and seedlings (in relatively high quantity) till 20 days after sowing in all the three dosages viz. 6, 12.5 and 25.0 ml kg^{-1} seed but the residues reduced to below detectable levels in kernels and haulms. These results suggest that the mortality of the grubs in chlorpyriphos seed treatment might be a result of contact toxicity in the soil and also due to ingestion of the chemical by feeding on the roots.

INTRODUCTION

CHAPTER I

INTRODUCTION

Groundnut or peanut (*Arachis hypogaea* L.) is a dietary supplement in developed countries where it is eaten raw, roasted, boiled and as sauce. Groundnut supplies essential amino acids, lipids, vitamins and minerals to the diets of many in the developing countries. It is the second most Important source of vegetable oil in the world. Groundnut contributes 55% of the nation's vegetable oil from 45% of the land devoted to oil seed. In most years, the cost of importing this product is second only to that of fuel oil. It is grown on 8.5 m ha producing 8.4 million tonnes of pods, an average production of 0.99 t ha-' (FAO, 1994).

Insect pests are recognized as one of the major constraints in groundnut production. 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. Wightman and Amin (1988) briefly discussed pests of groundnut in semi-arid tropics and Amin (1988) reviewed the Indian situation. More recently Wightman and Ranga Rao (1994) described the insect taxa most likely to be associated with reduced groundnut production together with an indication of their distribution and kind of damage they cause. Wightman *et al.* (1990) categorized four cohorts of insects affecting groundnut, nonviruliferous foliage feeders, viruliferous foliage feeders (virus vectors), invertebrates living in the soil that feed on underground plant parts and those that feed on harvested and stored pods and kernels. The insects that live in the soil of groundnut fields are responsible for higher levels of yield loss than foliage feeders. They attack pods and roots and foliage via the roots.

Soil insects are difficult to manage because farmers usually do not know that they are present until plants die or until the crop is harvested. One of the most important soil pests affecting groundnut is white grubs. These are the larval stage of beetles of the family Scarabaeidae. The adults are popularly known in Europe as chafer beetles, May or June beetles. The grubs live in the soil and feed on the roots of plants. Many crop species, especially cereals are able to tolerate the damage to some extent, but severe problems arise when crops with vulnerable root systems like groundnut are sown in white grub endemic areas. White grubs are pests of national importance in India and are a serious constraint to the production of rainy season crops. In endemic areas, the damage to groundnut ranges from 20-100%. The presence of one grub/M^2 may cause 80-100 per cent plant mortality (Yadava and Sharma,1995). Yield reduction occurs because larvae kill plants in the seedling stage and impair pod production by weakening the plants. White grubs also damage pods causing direct yield losses (Anitha, 1992). Maximum damage occurs when the grubs are in 3rd instar.

There are more than 50 pest species of white grub in the Indian subcontinent of which 12 are key pests attacking several crops in different regions of the country (Yadava and Sharma 1995). *Holotrichia consanguinea* Blanch. is the most serious constraint to groundnut cultivation in northern India whereas *H. serrata* (F) is common in southern and northern India. Extensive research has been done on the distribution and control strategies of these two pests. About 80,000 ha of groundnut has been reported to be affected by white grubs in Andhra Pradesh (Wightman, 1995), but very little attention has been paid to the white grub problem in this state. There is some ambiguity about the identity of the species involved and its biology.

Seed treatment with chlorpyriphos 20 EC has been found to be the most effective and economical method for white grub control in groundnut. However, different dosages of this insecticide are being used for seed treatment in different parts of India. Very little work has been done about the insecticides and its effective dose that controls the species of root grub prevalent in Andhra Pradesh. Information gathered from farmers and other researchers show that seed treatment with chlorpyriphos which is a national recommendation is effective for only 25 to 30 days. The beetles emerging late would still be a problem as the insecticides would have lost its effect by the time the adults lay eggs and the grubs hatch. Eventhough chlorpyriphos has been recommended as seed dressing chemical against root grubs, method of application has not been standardised and testa damage during treatment resulting in no germination is the problem faced by the farmers. Pelleting using inert material, adhesive and insecticide increases germination rate without damaging testa, helps in better distribution on the insecticide, regulates the release of insecticide, provides better protection for seeds against fungi and insects in addition to increasing the water holding capacity of the seed. Attempts of pelletization in groundnut seed are lacking. In view of the increasing problem of development of resistance to different groups of insecticides available at present attempts need to be made to explore newer groups of insecticides for the control of root grubs. Imidacloprid, a new chloronicotinyl systemic insecticide also with a very good contact and stomach action, showed superior performance against sucking pests and coleopteran species (Elbert *et al*, 1990). This compound is mainly used as a seed dresser with high safety margin and offers a powerful alternative to release the resistance pressure on other valuable groups of insecticides (Leicht, 1993). Its efficacy as seed dresser against root grubs is yet to be studied. Groundnut being an oilseed crop the risk of the economic product (kernels) retaining the residues of toxic chemicals is ever present if higher doses and more toxic chemicals are used. Since a lot of gaps exist in the literature pertaining to identity, biology

and management strategies for the white grub species associated with groundnut in Andhra Pradesh, the present study was undertaken with the following objectives:

- Identification of the white grub species associated with the groundnut ecosystem in Andhra Pradesh..
- Study of the life history of the predominant species.
- Chemical control of white grubs by seed treatment.
- Development of a seed pelleting technique
- Estimation of pesticide residues in soil, kernel and haulms following seed treatment with recommended insecticide.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

2.1 WHITE GRUBS AS PESTS OF GROUNDNUT

'White grubs' or 'root grubs' are the larvae of Scarab beetles popularly known as cock chafers, leaf chafers, chafer beetles, May beetles or June beetles. They belong to family Scarabaeidae of order Coleoptera. The grubs are subterranean and feed on living roots. These are polyphagous and feed on the roots of a wide variety of cultivated as well as uncultivated plants. Almost all field crops grown during the rainy season in India are damaged viz., groundnut, sugarcane, pearl millet, sorghum, cowpea, pigeonpea, green gram, cluster bean, chillies, upland paddy etc. The plantation crops like tea and coffee suffer similar damage in seedling and early growth stages. The adult beetles like the grubs are polyphagous and feed on 250 different host trees. An attempt has been made to review the available literature on the white grubs attacking groundnut in India, and in particular Andhra Pradesh. The other aspects covered are the biology, chemical control by seed treatment, seed pelleting and insecticide residues.

2.2 OCCURRENCE

Wightman and Ranga Rao (1994) reviewed the scarabaeids causing damage to groundnut in the world. Four species of *Holotrichia*, *H. formosana, H. oblita, H. parallela, H. sauteri* (Lu *et al*, 1987; Wang *et al,* 1986; Huang and Lin, 1987), *Maladera orientalis* (Wang *et al,* 1986), *Heteronyx diomphalia* (Shang *et al,* 1981), *corpulenta (Xu* , 1982) were reported from China. Smith and Barfield (1982) listed *Anomala antiqua* and *Xylotrupes gideon* from Burma and *A. atrovirens* in Indonesia. Cho *et al*. (1989) recorded *Anomala rufocuprea, Heteronyx diomphalia, Holotrichia morosa and Maladera orientalis* infesting groundnut in Korea. *Leucopholis irrorata* in Philippines (Cadapan and Escano, 1991) and

Maladera sp. were reported from Thailand. Four species of *Heteronyx, Lachnosterna caudata, Lepidiota* sp., two species of *Sericesthis, Rhopaea magicornis* were reported in Australia by Smith and Barfield (1982), Gough and Brown (1988) and Rogers *et al*, (1992).

Coming to the Americas, Smith and Barfield (1982) recorded *Phyllophaga spp , Popillia japonica and Strigoderma arboricola* as pests of groundnut. Wide range of white grubs were reported from Africa by Smith and Barfield (1982) and Wightman and Ranga Rao (1 994).

White grub problem in groundnut in India has been reviewed by a number of researchers time and again. Pal (1977) has given a detailed list of endemic grub pockets in various states and also the species involved. In Gujarat, Rajasthan, Bihar, Uttar Pradesh and Punjab *Holotrichia consanguinea* Blanchard was the predominant species. *Holotrichia serrata* Fabricius was reported to be a serious pest of groundnut in Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh. *Holotrichia reynaudi* Blanchard was stated to be the major species in Karnataka, Andhra Pradesh and Tamil Nadu (Yadava and Sharma, 1995). Apart from these two predominant species, *Lachnosterna fissa* in Haryana, *Holotrichia insularis* Brenske, *Schizonycha ruficollis* Fabricius, *Anomala bengalensis* Blanchard, *Aserica spp., Serica assamensis* Brenske in Rajasthan (Pal, 1977) and *Maladera* sp. in Canal Command area of Rajasthan (Yadava, 1991) were also recorded. In eastern Uttar Pradesh, Nath and Singh (1987) recorded 8 melolonthids and 8 rutelinids in a groundnut - sugarcane ecosystem. *Apogonia ferruginea* Fabricius., *Apogonia uniformis* B., *Apogonia roucca, A.. cribricollis* Burmeister., *Autoserica nathani, A.. atratula* Dalla Torre, *A.. insanabilis* Brenske and *Schizonycha ruficollis* Fab. were the melolonthids recovered. Rutelinids associated with this crop were *Anomala bengalensis* Blanch., *A.. dorsalis* Fabr., *A.. dorsalis var. fraterna* Burm., *A.. ruficapilla* Burm., *Adoretes versutus* Harold , *A.. decanus, A.. limbatus* Bl., and *A .laisopagos* Bm.

In Andhra Pradesh, the earliest report of white grub incidence in the groundnut crop was by Husain (1974). In the groundnut growing belt of Andhra Pradesh, particularly in the districts of Anantapur, Kurnool and Hyderabad the species identified as *Holotrichia consanguinea or Phyllophaga consanguinea* was found to be the key pest causing severe losses in the rainy seasons of 1968 and 1969 whereas *Holotrichia serrata* F. was also recorded from 5000 hactares in the sandy soil tracts of Gooty, Kalyandurg and Uravakonda taluks of Anantapur and Dhone, Pattikonda taluks in Kurnool district (Pal, 1977). However, Rao *et al*, (1976) reported 10,000 ha in Kurnool and Anantapur districts as affected by white grubs. *Anomala varians, Schizonycha ruficollis* and *Phyllognathus* sp. were the other species identified in this endemic area. Yadava and Sharma (1995) reported *H. reynaudi* to be the major species affecting groundnut in Andhra Pradesh where 80,000 ha has been reported to be infested (Wightman, 1995).

2.3 NATURE AND EXTENT OF DAMAGE

The white grubs feed on the roots, causing the plant to show, varying degrees of yellowing, wilting and die ultimately. The roots show a sharp cut which can be differentiated from termite damage. The affected plants can be pulled up easily. Patches of dead plants are seen throughout the field which later coalesce to produce intensive areas of damage (Yadava, 1991). White grubs have been reported to be pod borers too (Anitha, 1992). The presence of one grub m^{-2} may cause mortality of 80-100 percent plants. Because of the taproot system and smaller amount of roots, the damage to groundnut is more pronounced as compared to fibrous rooted crops. *H. consanguinea* was found to cause 50-100% damage to groundnut (Joshi *et al*, 1969, Sharma and Shinde, 1970 and Yadava *et al,* 1978). Yadava (1991) reported 20-100% plant mortality in *H. consanguinea* affected areas, 10-60% in *H. serrata* areas. Husain (1974) recorded 100% damage in vast tracts extending from 320-400 m^2 in 1968 and 1969 in Andhra Pradesh. Pal (1977) reported 5000 ha to be affected in Andhra Pradesh. Rao *et al*, (1976) reported 10,000 ha in

localized areas of Gooty, Kalyandurg and Penukonda areas of Anantapur and Dhone and Pattikonda of Kurnool where a crop loss of 60-80% annually was recorded. Wightman (1995) reported 80,000 ha as affected by white grubs. The damage caused was reported to be 30-40% (AICRP (white grub) 1995a).

2.4 ADULT HOST PREFERENCES

2.4.1 *Holotrichia serrata*

Pal (1977) reported that the adult beetles of *H. serrata* were attracted to neem *(Azadirachta indica),* acacia *(Acacia arabica),* ber *(Zizyphus zujuba),* guava *(Psidium guajava).* Yadava and Sharma (1995) included palas *(Butea monosperma)* as a host of this species apart from the above mentioned hosts.

2.4.2 *Holotrichia consanguinea*

Husain (1974) listed banyan *(Ficus bengalensis),* drumstick *(Moringa oleifera),* tamarind *(Tamarindus indica),* neem *(Azadirachta indica),* ficus (Gular) *(Ficus glomerata),* babul *(Acacia arabica),* guava *(Psidium guajava),* sapota *(Achras sapota),* mosambi *(Limeicidan tanaka),* gulmohar *(Poinciana regia)* as hosts of *H. consanguinea* The most preferred host trees were drumstick and gulmohar. The hosts of second preference were tamarind, neem, banyan and guava. The beetles are polyphagous and may feed on a variety of host trees. However, some preference was exhibited towards hosts like jijube (ber), neem, cluster fig (gular), jambolana (Jamun) and drumstick (Sainjana) (Yadava and Sharma, 1995). Bakhetia and Brar (1985) studied the white grub problem in Punjab and listed almonds *(Amygdalus communis),* ber *(Zizyphus mauritiana),* guava *(Psidium guajava),* Kachnar *(Bauhinia variegata)* and rukmanjani *(Lagerstroemia indica)* as the most preferred hosts of *H. consanguinea (*Bindra and Singh, 1971, Brar, 1980).

Table 1: Host range of some important species of white grubs

S.No	Species	Stage	Host plants
1.	*H. consanguinea* Blanchard	Adults	*Amygdalus communis* (almond), *Azadirachta indica* (neem), *Carisa carandus* (karaunda), *C. fistula* (amaltas), *Citrus* sp., *Dalbergia sisso* (shisham), *Delonix regia* (gulmohar), *Eugenia jambalanivillae robusta* (silver oak), *Grewia asiatica* (falsa), *Lagerstronia indica* (rukmanjani), *Mangifera indica* (mango), *Morus alba* (mulberry), *Prosopis cineraria* (khejri), *P.jubifera* (khejra), *Primat persica* (peach),*Psidium guajava* (guava). *Punica granatum* (pomergranate), *Pyrus pyrifolia, Rosa sp.* (Rose), *Saraca indica* (ashoka), *Terminalia arjuna* (arjuna) and *Zizyphus mauritiana* (ber).
		Grubs	*Arachis hypogaea* (groundnut), *Brassica campestris* (mustard), *B.capitata* (cabbage), *B.oleracea* (cauliflower), *Cajanus cajan* (arhar), *Capsicum frutescens* (chillies), *Cicer arietinum* (bengal gram), *Crotalaria juncea* (sunhemp), *Gossypium sp.* (cotton), *Hordeum vulgare* (barley), *Medicago sativa* (lucerne), *Pennisetum typhoides* (bajra), *Pisum sativum* (peas), *Raphanus sativus* (radish), *Ricinus communis* (castor), *Saccharum officinarum* (sugarcane), *Sesamum indicum* (sesamum), *Solanum melongena* (brinjal), *Sorghum vulgare* (jowar), *Trifolium alexandrium* (Egyptian clover), *Triticum vulgare* and *Zea mays* (maize).
2.	*H. serrata* Fabr.	Adults	*Acacia arabica* (babool), *Achras sapota* (sapota), *Amaltas ber*, *Butea monosperma* (palas), *Canna indica*, *Ficus religiosa*, gular, guava, mango, *Moringa pterygosterma*, mulberry, *Musa sapientam*, neem, *Origeinia oojeinensis*(sandan), *Pithecolobium dulca*, *Prunus malus*, *P. persica*, rose, *Scheichera alcosa* (kusum) *Swietenia machagoni*, *Syzigium jambolanum*, *Vitis vinifera* (grapevine) and *Zizyphus xylopyra* (ghont).
		Grubs	*Allium cepa* (onion), bajra, *Citronella*, sp., chillies, *Eucalyptus* sp., groundnut, jowar, *Nicotiana* sp. (tobacco), palas, *Phaseolus aureus* (moong), sandan, sugarcane, *Trticum aestivum*, tur and *Ventiveria zizaniodes* (Khas).

S.No.	Species	stage	Host plants
3.	*H. insularis* Brenske	Adults	Ber, babool, *Crataeva religiosa* (berne), falsa, *Moringa oleifera* (drumstick or sainjana), jamun, Karaunda, *Lawsonia inermis* (mehndi), mango, neem, pomegranate, sesamum and tamarind (imli).
		Grubs	*Abelmoschus esculentus* (okra), bajra, brinjal, chillies, cucrubits, groundnut, jowar, maize, sunhemp, sugarcane, and *Vigna sinensis.*
4.	*Anomala bengalensis* Bl.	Adults	Falsa,grapevine, mulberry and rukmanjani
		Grubs	Bajra, chillies, groundnut, maize,sorghum and sugarcane.
5.	*Schizonyca ruficollis* (Fabr.)	Adults	Grapevine and rukmanjani
		Grubs	Groundnut and sugarcane

2.4.3 *Holotrichia insularis*

Srivastava and Khan (1963) studied the bionomics of *H. insularis* in Rajasthan and found that the adult beetles showed a decided preference for drumstick *(Moringa oleifera).* Appreciable damage was also noted in carandas plum *(Carissa carandas),* guava *(Psidium guajava),* neem *(Azadirachta indica),* java plum *(Engenia jambolana) and* Egyptian privet *(Lawsonia inermis).*

Brar and Sandhu (1980a) reviewed and listed the adult and grub hosts of *Holotrichia consanguinea, H. serrata, H. insularis, Anomala bengalensis and Schizonycha ruficollis* (Table 1).

2.5 BIOLOGY

Several workers have worked out the biology of *Holotrichia consanguinea, H. serrata and* H. *insularis* the predominant species attacking groundnut. Brar and Sandhu (1980a) reviewed their work which is presented in Table 2.

Beetles emerge from soil shortly after heavy premonsoon or monsoon showers at dusk between 7-8 p.m. Mating takes place immediately after emergence. The females emerge first and release sex pheromone to attract the male. They settle on a preferred host. The male alights on the female and copulation takes place while the male is inverted and the hindlegs of both the partners are interlocked. The mating lasts for 4 to 7 minutes in *H. consanguinea,* 15 minutes in *H. insularis* and 5 to 15 minutes in *H. serrata.*

Pre-oviposition period varies with the species and it is 2-8 days in *H. consanguinea,* 4 to 6 days in *H. insularis* and 5 to 15 days in *H. serrata.* The females of *H. consanguinea*

Table 2 Biology of important species of white grubs

S No	Species of white grub	Mating Period (min)	pre-ovi-position period (days)	Ovipo-sition period (days)	Post ovi-position period (days)	Fecun-dity	incuba-tion period (days)	Larval period (days)	Pupal period (days)	Adult longe-vity (days)	author(s)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	*Holotrichia consanguinea* Blanchard						7-21	42-56			Prasad and Thakur, 1959
							8-10	56-70	12-16		Kalra and Kulshreshtha, 1961
								56-70	28-42		Desai and patel, 1965
				20	7-8		18				Patel *et al*, 1967
							7-10		13		Rai *et al*, 1969
							7-8	3 months (larval+ pupal)			Bindra and singh, 1971
		4 3	23	35	26 7	18	9 4 -12 4			32 8 (males)	Annual Report, Dept of Entomology, PAU 1974
		5-7	6-8	5-7	4 -7	8-25	8-10	114 -120	16-18	13 - 17	Yadava and Saxena 1977,
2	*H serrata* Fabr	5-7							7-10		Krishnaswami *et al*, 1963
		5-7	37-86	17-57		64 4	8-13	148 7	11	78-266	Majumdar and Teotia, 1965

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
		5-15	5-6			8	7-10	142-178	14-24		David and Kalra, 1966
									18-26		David and Anantha-narayana, 1974
							8-10	6-8 Months	14-21		Raodeo, 1974
						25-30	8-10		12		Veeresh, 1975
		4-5	28-215	15		26	10-12	163 9	12	15	Veeresh,1997
3	*H insulans* Brenske	15	4-6			30	8-12		15-22		Srivastava and Khan, 1963

lay eggs for 5 to 7 days, and 28 days to 7 months after mating in *H serrata* Post oviposition period was reported to be 2 to 7 days in *H consanguinea*

The eggs of *H consanguinea* are laid in moist sandy or loose soils at 5 to 15 cm depth singly or in batches but *H serrata* lay eggs in earthen cells at a depth of 8 to 16 cm Single female of *H consanguinea* lays 8 to 25 eggs and 30 eggs in case of *H insularis* The freshly laid oval creamy white eggs of *H consanguinea* measure 2 8 to 3 4 mm in length and 1 5 to 2 0 mm in breadth The eggs of *H serrata* are 3 0 mm long and 1 7 mm broad and 3 5 mm long and 1 5 mm wide in *H insularis* The eggs before hatching become enlarged and spherical and colour changes to dirty white The eggs of *H consanguinea* hatch in 7 to 21 days The incubation period in *H insularis* is 8 to 12 days and 7 to 13 days in H *serrata*

There are three larval instars in root grubs The first instar larvae are generally creamy white and consume small rootlets rather slowly The head capsule of newly emerged grub is wider than the thorax and abdomen, but as grubs grow the thorax and abdomen become wider than head capsule The second instar is active, but most of the damage is done by third instar The larval period is completed in 6 to 11 weeks in *H consanguinea* and 5 to 8 months in *H serrata* In case of *H insularis* the first instar lasts for 8 to15 days, the second instar for 21 to 28 days and the third instar period has not been mentioned (Brar and Sandhu 1980a)

The freshly formed pupa is white or light yellow and ultimately turning to brown The pupa is exarate and is naked in case of *H consanguinea* but it is enclosed in earthen cells in *H serrata and H insularis* The cells of *H insularis* measured 32 mm long and 14 mm wide The pupal period is completed in 12 to 42 days in *H consanguinea* in 15 to 22 days in *H insularis* and 7-26 days in *H serrata*

The newly emerged beetle is cream coloured with soft white elytra, with lapse of time the colour changes to brown and elytra hardens The females are slightly larger than males The adult beetles formed in October-November are not mature sexually till March April and come out of soil only after premonsoon rains

The total life cycle from egg to adult is 100 to 144 days in *H consanguinea* 197 to 231 days in *H serrata* in Rajasthan (Yadava, 1991) In case of *H insularis* the life cycle is completed in 11 to 16 weeks

2.6 CHEMICAL CONTROL OF WHITE GRUBS BY SEED TREATMENT

Wightman *et al*, (1990) reviewed the chemical control measures recommended for control of grubs of *H consanguinea* (Table 3)

2.6.1. Seed treatment with chlorpyriphos

Seed treatment has been found to be the most effective and economical method for control of white grubs A number of studies have been conducted on the control of white grubs by seed treatment some of which have been very effective

Bakhetia (1982) conducted field trials in Ludhiana and Samrala farms in Punjab from 1972-79 where seed treatment and seed soaking were tested against white grub *Holotrichia consanguinea* using carbofuran 50 SD, fenitrothion 50 WP and 50 EC, phoxim 50 EC, chlorpyriphos 20 EC, aldrin 30 EC, isofenphos 50 EC and 40 SD at variable dosages Seed soaking affected the germination adversely but germination was normal with seed treatment Except aldrin, all the insecticides gave very good protection against white grubs Chlorpyriphos 20 EC @ 5 g a i kg^{1} seed was found to be very effective in controlling the grub and also increasing the yield

Table 3. Insecticides recommended for the control of white grubs in groundnut

Species	Insecticide	Rate (kg a.i. ha^{-1})	Reference
Holotrichia consanguinea	Phorate 10 G	1-3	Bakhetia, 1982a
		1.0	Brar and Sandhu, 1980a,b
		2.5	Ram and Yadava, 1982 Vishwa Nath and Srivastava, 1981
		1.5	Siva Rao *et al.*, 1984
		SC	Ram and Yadava, 1982
	Carbofuran 3 G	1-3	Bakhetia, 1982a Brar and Sandhu, 1980a,b; Bakhetia *et al*, 1982
		1.5	Siva Rao *et al*, 1984
		SC	Bakhetia, 1982b; Ram and Yadava, 1982
	Isofenphos 5 G	1-3	Bakhetia, 1982a
		1.0	Brar and Sandhu, 1980
		SC	Bakhetia, 1982b
	Quinalphos 5 G	1.0	Bakhetia, 1982b
	Quinalphos 25 EC		Bakhetia, 1982b
	Dazomet 10 G	2.5	Vishwa Nath and Srivastava, 1981
	Heptachlor (10% dust)	2.5	Vishwa Nath and Srivastava, 1981
	Fensulfothion 5 G	1.0	Bakhetia *et al*, 1982
	Chlorpyriphos	SC	Bakhetia, 1982b
	Phoxim	SC	Bakhetia, 1982b
	Fenitrothion	SC	Bakhetia, 1982b

SC = Seed Coating.

Field experiments were conducted at Tirupathi to compare the influence of 4 granular insecticides (phorate, carbofuran, sevidol and quinalphos applied to the soil at 1.5 kg a.i. ha^{-1} at sowing), three seed treatments (isofenfos, chlorpyriphos and carbofuran @ 2.5 g a.i. kg^{-1} seed) and neem cake incorporated into soil @ 100 kg ha^{-1} on growth and yield of groundnut besides controlling insect pests. Seedling emergence and final plant population were significantly low in chlorpyriphos treated seeds. The seeds were treated @ 2.5 g a.i. kg^{-1} seed. The results show that there was no significant difference in the control of root grubs between the treatments. However, pod yield was badly affected in chlorpyriphos treated seed with 998 kg ha^{-1} as against 1332 kg ha^{-1} in control (Siva Rao *et al*, 1984).

Ram and Yadava (1982) tested 15 insecticides as seed coating and seed dressing against white grub in groundnut fields in Jobner, Rajasthan. The insecticides tested were phorate, carbofuran, counter, sevidol, aldicarb as granules, chlorpyriphos, quinalphos, phosphomidon, diazinon, methyl demeton, aldrin, endosulfon and lindane as EC formulations. The seed coating was done by taking clay soil, water and seeds in 1:3:16 ratio. A slurry was prepared using clay soil and water and the insecticide dissolved in it and later the seeds were coated with it by putting in a container and shaking it for 5 minutes. The coated seeds were shade dried on a cement floor 12 hours before sowing. The seed dressing was done by directly adding insecticide to seed. Quinalphos 25 EC SD @ 1 L 80 kg^{-1} seed, counter 5 GC 25 kg ha^{-1}, lindane 20 EC SD,methyl demeton 25 EC SD 1 L 80 kg^{-1} seed, sevidol 4.4g SC, chlorpyriphos 20 EC SD 1 L/80 kg, diazinon 20 EC SD 1 L 80 kg^{-1} appeared promising as plant mortality in these treatments ranged from 10.4 to 15.7% as compared to 39.1 % in untreated control.

Srivastava *et al.* (1982) undertook for the first time seed treatment of groundnut with chlorpyriphos @ 25 ml kg^{-1} seed which gave protection against white grubs

Holotrichia consanguinea and increased the yield of the crop. Srivasthava *et al*, (1986) tested carbofuran 50 FP 5 g kg^{-1}, 7.5 g kg^{-1}, 10 g kg^{-1}, chlorpyriphos 20 EC 12.5 ml, 18.7 ml, 25 ml kg^{-1} seed, chlorpyriphos 20 ml kg^{-1} + bavistin 2 g kg^{-1}, chlorpyriphos 20 ml kg^{-1} + thiram 2 g kg^{-1} against white grub by recording the plant mortality, grub mortality and yield. Chlorpyriphos + bavistin, chlorpyriphos + thiram and chlorpyriphos 25 ml kg^{-1} seed as seed dresser were found to be most effective in reducing grub populations as compared to untreated plot. Maximum number of plants were also present in the plots treated with chlorpyriphos and its combinations.

Kumawat and Yadava (1990) used granular insecticides like phorate, landrin and sevidol as pre-sowing soil treatment, sevidol, carbofuran, isofenphos, phorate as seed coating and chlorpyriphos as seed dressing against *H consanguinea.* Phorate ST (2.5 ai 1 g ha^{-1}) proved to be most effective in checking plant mortality and maintaining low grub populations. Landrin ST (2 kg a.i.ha^{-1}), isofenfos SC (4 kg a.i ha^{-1}), isofenfos SD (0.24 L a.i. ha^{-1}), phorate SC (1 kg a.i. ha^{-1}) were found to be on par with phorate ST. Chlorpyriphos SD (0.2 L a.i. ha^{-1}) was found to be least effective against white grub.

Agrawal (1990) reported that chlorpyriphos 20 EC @ 25 ml kg^{-1} seed resulted in better control of white grub incidence in Uttar Pradesh. The yield was also high (37.04 q ha^{-1}). The sequence of effectiveness of insecticides was given as. phorate 10 G (soil treatment) > chlorpyriphos 20 EC 25 ml kg^{-1} seed > carbofuran 50 SP (SR 3%) > carbosulfon 50 SP (SR 2%) > carbosulfon 25% at 1.0 a. i. > quinalphos 25 ml kg^{-1} seed > carbofuran SP (SR 1 %) > neem oil 25 ml kg^{-1} seed > carbosulfon 5% at 0.75 a.i. > neem kernel extract.

Yadava (1991) has recommended the use of seed treatment with chlorpyriphos as the most economical form of chemical control for grubs in groundnut in monsoon sown crop (rainfed /irrigated) or a standing crop. For a monsoon sown crop, seed treatment with

chlorpyriphos 20 EC or quinalphos 25 EC at 25 ml kg^{-1} seed was found to be quite effective. Pre-sowing soil treatment with phorate 10 G at 25 kg ha^{-1} or quinalphos 5 G at 25 kg ha^{-1} was suggested as an alternative to seed treatment. For advance sown crop, seed treatment or soil treatment are ineffective. For such crop application of quinalphos 25 EC or chlorpyriphos 20 EC at 4 L ha^{-1} with irrigation water should be done between first week of July to second week of August.

In Gujarat in 1993-94, the effect of seed treatment on groundnut seeds was tested in the laboratory. Quinalphos 25 EC @ 20 and 25 ml kg^{-1} seed, chlorpyriphos 20 EC @ 20 and 25 ml kg^{-1} seed, nimbosol 25 ml and nimbicidin 25 ml were the insecticides tested and they did not cause any hinderance to germination. Further chemical control trials were also done to assess the efficacy of various insecticides as granular treatment, seed treatment and soil treatment. Soil application of phorate 10 G @ 25 kg ha^{-1} and seed treatment with quinalphos and chlorpyriphos @ 20 or 25 ml kg^{-1} seeds were most effective in checking white grub populations and resulted in higher yield of groundnut. Similar results were also reported from Deesa in north Gujarat where quinalphos 25 EC @ 25 ml and 20 ml kg^{-1} seed was the most effective followed by chlorpyriphos. Keeping these results in view, the following seed treatments were recommended for control of white grub in kharif groundnut under northern Gujarat conditions.

1. Seed treatment with quinalphos 25% EC @ 20 ml kg^{-1} seed
2. Seed treatment with chlorpyriphos 20% EC @ 20 ml kg^{-1} seed. (AICRP (White grubs) 1995b).

2.6.2. Imidacloprid - A seed dressing chemical

Imidacloprid is a chloronicotinyl systemic insecticide with a very good root systemic action and with contact and stomach action (Tomlin, 1994). The compound

showed superior performance on sucking pests like plant hoppers and aphids as well as on various coleopteran species, but was less effective against lepidopteran larvae. It was found to be effective against coleopterans (*Atomaria sp., Leptinotarsa decimlineata, Lissorhoptrus oryzophilus, Lema oryzae)* Dipterans (*Oscinellla frit* and *Pegomya* spp.) and Lepidopterans (*Lithocolletis* spp.) (Elbert *et al,* 1990).

In rice all important hopper and beetle species can be controlled by imidacloprid. Granules are applied in nursery boxes shortly after transplanting (0.2 - 0.3 kg ai ha^{-1}) to the field. The compound was registered under the trade name of Admire in Japan and confers protection against early season pests, most important in rice cultivation. In France, Belgium and Spain imidacloprid is registered as Gaucho. In these countries sugarbeet seeds are pelleted with this insecticide, which protects the crop against the early season pests like pigmy marigold beetle (*Atomari linearis*) and wirworm (*Agriotes* sp.) as well as against various aphid spp. at an application rate of 117 g a.i. ha^{-1}. (Leicht 1993).

2.7 CHLORPYRIPHOS RESIDUES

Literature regarding residues of chlorpyriphos in groundnut is lacking. Very little information is available about residue analysis for chlorpyriphos following seed treatment in other crops also. However some related studies have been reviewed hereunder.

Logan *et al,* (1992) analysed the residues of chlorpyriphos in soil and plant and kernels samples following application of chlorpyriphos granules @ 5 kg a.i.ha^{-1} and chlorpyriphos as seed dressing @ 5 g a.i. kg^{-1} seed for the control of termites. Residues of chlorpyriphos were detected in all haulm and kernel samples. Concentrations in the kernels varied from trace levels to 0.79 mg kg^{-1} Residues were detectable in the soil 92 days after application.

Studies were conducted in Ontario, with granular insecticides chlorfenvinphos, chlorpyriphos, isofenphos for the control of onion maggot *Delia antiqua* in organic soil chlorpyriphos and isofenphos were more persistent in organic soil and except chlorpyriphos all other insecticides decreased below half the original level by September Significant residues of each of the 4 insecticides were detected in immature bulbs (64 to 76 days after seeding) with the level of residue being much higher in the roots and outer skin. Ninety six days after seeding (2 months before harvest) insecticide residues in the bulbs were below detectable levels (Ritcey *et al*, 1991).

Paddy seedlings subjected to rootdip with chlorpyriphos 20 EC @ 0 02% were analysed for residues by GC at 0, 10, 20 and 30 days after transplanting. The residues decreased from 1.6672 mg kg^{-1} on '0' day to 0.2661 mg kg^{-1} on the 30th day. But these were below the MRL of 2 mg kg^{-1} (Annual Report - AICRP (Pesticide residues), 1995c).

2.8 SEED PELLETING

Pelleting was introduced in America in the 1940's and into Europe about 2 decades later (Halmer, 1988). Pelleting materials are used to build irregularly shaped seeds into uniform spheres facilitating precision drilling in order to achieve optimum plant stand. Halmer (1988) describes the pelleting process as one where, by rolling seeds together with fillers and binders and gradually adding water followed by drying, incremental layer can be added to seeds until correct size grade of pellet is reached. Pesticides can be added discretely to different layers of the pellet or can be mixed throughout the pelleting matrix.

A modified thiram soak treatment was incorporated into a pelleting process in U.K. (Durrant *et al*, 1988). In addition hymexazol or maneb are added to control pre-emergence damping off fungi and methiocarb to act against pests such as wireworms. There appears to be little loss of material from the pellets, deposition of insecticide is uniform (ca 23%) with

high recovery (98%) when pelleting is done by Germans EB process as against other methods (Halmer, 1988).

A general problem with this commercially well established technology is that there is insufficient published information to gauge the reproducibility with which chemicals and other materials are retained in the pellets (Maude, 1990).

The inerts used may be dolomite, lime, or charcoal. The adhesives used may be gum arabic, gelatin, caesin and fevicol (1 ml 10 g^{-1} of seed), rice gruel, starch. The pelletization increases germination rate and seedling vigour. It provides better protection for seedlings against fungi or insect pests. Pellets may be coloured so that birds and rodents may not recognize the seeds. It also increases the water holding capacity of the seed .

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The present investigations were carried out on the applied ecology of white grub species in Andhra Pradesh in the groundnut ecosystem and their management through seed treatment. Laboratory and field studies were conducted at ICRISAT Asia centre (IAC), Patancheru, Andhra Pradesh and Department of Entomology, College of Agriculture, Rajendranagar, ANGR Agricultural University, Andhra Pradesh. Surveys for the collection of white grub species were undertaken in the major groundnut growing areas of Andhra Pradesh. These studies were undertaken during May 1995 to December 1996.

3.1 COLLECTION AND IDENTIFICATION OF WHITE GRUBS

3.1.1 Collection of adult beetles

Surveys were taken up in five important groundnut growing areas in Andhra Pradesh in the rainy seasons of 1995 and 1996 to collect the chaffer beetles. In the rainy season of 1995 beetles were collected at Anantapur, Tirupathi, Kurnool, Mahbubnagar and ICRISAT Asia Centre (IAC) Patancheru. All the areas selected are known to be endemic for the occurrence of white grubs in groundnut. In the 1996 rainy season collections were done only from Anantapur, Tirupathi, Kurnool and IAC. Beetles were collected from May to August and also in October from trees,in particular neem *(Azadirachta indica),* wild ber *(Zizyphus* sp.), acacia (*Acacia arabica),* drumstick *(Moringa oleifera)* and others. The host trees were located on the roadside or in the fields in vast groundnut growing tracts in all the locations selected. The beetles were hand picked from the host trees at dusk from 7 PM to 11 PM. These were preserved in 75% ethyl alcohol and labelled giving details of date and place of collection, and host on which collected.

3.1.2 Collection of white grubs

The locations selected for beetle collection were also surveyed for the collection of grubs in the months of September and October in the rainy seasons of 1995 and 1996. Wilting groundnut plants and also plants dried prematurely in a row were uprooted and the soil at the root zone dug upto a depth of 20 cm with a scoop (trowel) to collect the grubs. The grubs collected were transferred to plastic cups with moist soil and brought to IAC for rearing. The grubs were released separately locationwise in small nethouses(100 x 50 cm). The bottom of the nethouse was filled with sand: FYM (1:5) mixture to a depth of 20 cm. Pearl millet seeds were sown in a relay fashion in the soil to provide root material to the grubs for feeding during their development.. The adults emerging from these cages were collected separately, preserved in 75% ethyl alcohol and labelled locationwise for identification of species.

3.1.3 Identification of species

The white grub adults collected during the surveys and also the adults emerging from the grubs collected were identified into different species based on the characters listed in Table 4 and Fig. 1. The adult beetles were identified or identification was confirmed with the help of Dr Musthak Ali, Associate Professor, Department of entomology, GKVK, University of Agricultural Sciences, Bangalore 560065.

3.2 LIFE CYCLE STUDIES OF PREDOMINANT SPECIES

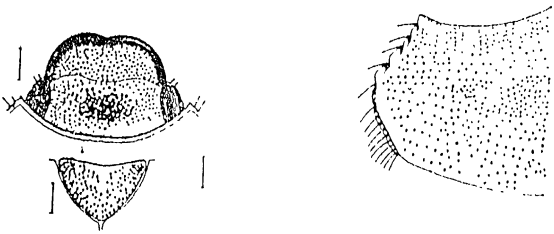
Holotrichia reynaudi is the predominant species collected from the groundnut growing areas. Biology of this species was studied in the rainy season of 1996-97. The adult beetles of *H. reynaudi* collected in June, from wild ber at Anantapur were used to study the biology in the laboratory. For this purpose the beetles collected were brought to

Table 4 Morphological features distinguishing *H reynaudi*, *H serrata* and *S ruficollis*

Character	*Holotrichia reynaudi*	*Holotrichia serrata*	*Schizonycha ruficollis*
Shape,size and colour	Body oval,compact convex, 16-20 mm long, 29 0-11 0 mm broad,dull brown black to brown red	Elongated,compact robust and convex, 26mm long and 11 0 mm broad,dark brown pronotum, light brown elytra	Elongated, shining ferruginous, medium sized, 15 5 mm long and 6 0 mm broad
Head	Head strongly,densely and subrugosely punctate clypeus and with margin rounded and reflexed, very feebly exised in front, front less punctate anteviorly, vertex raised transversely	Clypeus one third as long as broad as base sides rounded, slightly raised, front margin deeply emarginate, Frons more thickly, very closely, rugose punctate at top and sparsely Anteriorly less than 1/3 frontal area, free,, sparsely punctate Vertex vary finely, shallowly, closely punctate	Clypeus one half as long as broad in front (5 10) front margin one half as broad as at base (10 20) rounded at sides, very lowly emarginate, margins broadly reflexed at sides and deeply reflexed in front, sparsely Punctate in two irregular rows, punctures without setae or Bristles, Frons scabrose
Thorax	Pronotum moderately strongly and thinly punctate, scutellum finely and a little closely punctate except some irregular longitudinal areas Foretibia strongly and bluntly tridentate tarsi tender, claws strongly toothed	Lateral margins of pronotum strongly serrate with long thick bristles in between the serrations which decrease gradually in size posteriorly Scutellum thickly, finely punctate along the anterior and sparingly elsewhere Elytra Slightly pruinose, very slightly shining, finely irregularly rather thickly punctate towards the posterior Punctures concentrated along the lateral borders	Lateral margins plainly serrate, fringed with long fulrous hairs Pronotum broadly rounded anterior and posterior angles obtuse,basalangle more sharply Scutellum with acutely converging sides posteriorly, sharply angular at back, punctures more and deep Elytra convex, sub cylindrical, amplıated basally and narrowed posteriorly punctures deep, thick, regular each with the distinct long white Seta anterior tibiae weekly Tridentate Anterior tarsus more

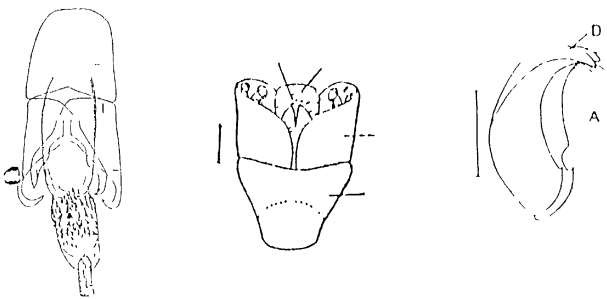
			Than twice as long as tibia
Character	*Holotrichia reynaudi*	*Holotrichia serrata*	*Schizonycha ruficollis*
Male genitalia	Phallobase a little narrower anteriorly Parameres strongly tapering and curved inwards posteriorly, each with its inner wall dorsally bearing a long acute, bisinuate painted plates slightly left before apex Aedegus long, tubular ,well sclerotized with two apodemes posteriorly Endophallus elongate, membranous closely set with a long highly sclerotized spatula at apex Coxites well developed and consolidated Bursa copulatrix exceptionally long, tubular and membranous spermatheca well developed, slightly curved, conical apically with spermathecal duct very long, convoluted near spermatheca, spermathecal gland also very long	Phallobase broad and elongated expanded towards the apex orifice basal, rounded and large parameres symmetrical, immovable broad separate, inner margin straight till more than half of the length than roundly curved outwardly Apex roundly and broadly folded, each paramere with a pair of short broad, lateral, inwardly connected processes with blunt rounded head like structures at the end Aedegus broad and membranous with amedian elongated strongly elongated, strongly bent and pointed process	Phallobase and parameres blindly united, basal attachment of phallobase on the inner margin with conical process and with a somewhat elongated depression near the base, phallobase elongated, broad, slightly ampliated medially Parameres, symmetrical, elongated, immovable, horizontal united posteriorly, broad at base, narrowed anteriorly, slightly expanded a little away from the rounded and blunt apex, profusely hairy along the inner margin at the apex
Reference	Mittal & Pajni (1977)	Khan & Ghai (1982)	Khan & Ghai (1980)

FIG -1 IDENTIFICATION CHARACTERS OF ADULTS OF [A] *H.reynaudi* , [B] *H. serrata* AND [C] *Schizonycha ruficolis*



I[A] *H.serrata* (a) HEAD (b) PRONOTUM (c) SCUTELLUM

Schizonycha ruficollis (a) HEAD (b) TERMINAL HIND TIBIAL SPURS (c) PYGIDIUM



1[C] MALE GENETALIA OF *H.reynaudi* , *H serrata* , *Schizonycha ruficollis*

the laboratory at IAC confining them in plastic containers half filled with moist soil. Circular oviposition cages with a diameter of 23 cm were used to confine one pair of beetles (1 F : 1 M) in each cage and 10 such pairs were utilised for the study. The cage was provided with a 10 cm layer of moist sand at the bottom. Small twigs of wild ber were provided as food and fresh twigs were replaced every day. Every day the soil was examined for eggs. Fecundity was not recorded because the exact date of emergence and mating were not known for the field collected beetles. The eggs collected were kept in petri dishes filled with fine sand kept moist by filter papers. After the eggs hatched, the grubs were transferred into petri dishes (9 cm diameter) with a mixture of 1:1 sand and organic manure. Care was taken to see that the soil mixture in the petri dish was kept moist. The petridishes were examined on alternate days to see if the grubs had moulted. The 2nd instars were then transferred to small plastic basins of 10 cm diameter filled with moist soil and organic matter in 1:1 ratio. Pearl millet seeds were sown in these dishes to provide root material for the grubs to feed on. Each dish contained ten 2nd instars which were observed once in 2 days for moulting. After moulting 3rd instars were transferred to plastic jars of 20 cm diameter, half filled with sand and organic matter mixture presown with pearl millet.Two grubs were released in each jar to avoid overcrowding. Pearl millet seeds were sown every 3 to 5 days to ensure uninterrupted supply of root material to the voracious 3rd instar larvae. The 3rd instar grubs were left in the same jars for pupation. Care was taken to see that the jars were kept moist. As soon as the pupa turned to adult it was transferred into the oviposition cages to observe the emergence.

The egg, larval and pupal periods were recorded. Size of freshly laid eggs and also just before hatching were recorded using a micrometer. In each instar,width of head capsule and length of grub were also recorded.

3.3 CONTROL OF WHITE GRUBS THROUGH SEED TREATMENT

Two experiments were conducted in the micro plots specially designed for the control of white grubs through seed treatment at IAC during 1995 and 1996 rainy seasons. Chlorpyriphos 20 EC @ 6 ml and 12.5 ml and another promising systemic insecticide imidacloprid 70 WS @ 5 g and 10 g kg^{-1} seed have been evaluated for their efficacy. Chlorpyriphos was selected as it is a national recommendation given by ICAR for kharif groundnut. *Holotrichia serrata* was the test insect used as it was the predominant species at IAC and could be easily reared.

3.3.1 Culturing *H. serrata*:

Adult beetles of *H. serrata* were collected from neem trees on the IAC farm between 1 st June and 31 st July 1995 from 7 PM to 11 PM. They were transferred to insectaries (8x3 m) that had 40cm of sieved, moistened sand on the floor. Leafy neem twigs were provided as food. Beetles laid eggs freely under these conditions in the soil. Groundnut and pearl millet seed were sown in the insectary to provide root material as food for the grubs hatching from the eggs .

3.3.2 Experiment I

In the rainy season of 1995 a trail was laid out in microplots or bays in alfisol RCE-20 at IAC. The experimental design was RBD with 5 treatments and 5 replications. The microplots are enclosures built of paving slabs in a hole dug in the ground. The bays were 0.5 m deep and measured 1.0 x 0.7 m (Plate. 1). They were filled with sieved alfisol. The seed treatment chemicals used were imidacloprid 70 WS @ 5 g and 10 g kg^{-1} seed, chlorpyriphos 20 EC @ 6 ml and 12.5 ml kg^{-1} seed and an untreated control.

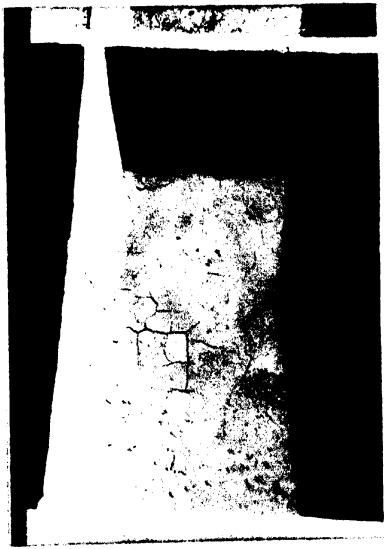


PLATE . 1 MICROPLOT USED IN SEED TREATMENT TRAILS

Seed treatment with chlorpyriphos was done adding the required quantity of the insecticide to the seed to be treated kept in a seed treating drum. After the addition of the insecticide, the drum was rotated gently for a few minutes for proper mixing of the chemical with seed. The treatment was done 12 hours before sowing and the seed was shade dried. Care was taken to see that the testa is not damaged during treatment. Imidacloprid which is available as water soluble powder was added to the seeds wetted with water to get proper coating on the seed. This was done 3 to 4 hrs before sowing. The plant stand was maintained at 30 plants/microplot. Twenty 2nd instar grubs of *Holotrichia serrata* reared in the insectary weighing 200mg on an average were released in each bay 20 days after sowing.

Destructive sampling was done to recover the grubs 15 days after release. The plants were uprooted and soil dug out in each bay. Percent plant mortality, percent larval mortality and larval weight gain were recorded.

3.3.3. Experiment II

During 1996 rainy season seed treatment with chlorpyriphos was evaluated against *H. serrata* by developing a seed pelleting technique. For this purpose groundnut seed was coated with 27% gum arabic @100 ml kg^{-1} seed in a seed treating drum. chlorpyriphos 20 EC @ 6 ml kg^{-1} seed was then coated on the same seed. Finely powdered gypsum @ 120 g kg^{-1} seed was sprinkled on the treated seeds to form the outer coat. The pelleted seed was then shade dried. The experiment was laid out in an RBD with 4 treatments, 5 replications and 4 sampling dates. The treatments were chlorpyriphos 20 EC @ 6 ml kg^{-1} seed, chlorpyriphos 6 ml kg^{-1} seed + gum arabic + gypsum seed pellet, imidacloprid 5 g kg^{-1} seed and untreated control. A plant stand of 30 plants/plot was maintained. The efficacy of the

seed treatment chemicals was evaluated by staggered release of the grubs at 20 DAS, 30 DAS and 40 DAS in separate set of plots.

In the first set where ten grubs were released at 20 DAS weighing 300 to 400mg destructive sampling was done 10 days after release. Counts on plant mortality, larval mortality and larval weight gain were recorded.

In the second set ten grubs were released at 20 DAS and recovered at harvest (110 days) by destructive sampling. The grubs weighed 300 to 400mg. Observations were taken on plant mortality and pod yield.

In the third set ten grubs weighing 900 to 1000 mg were released at 30 DAS and destructive sampling was done 10 days later (40 DAS). The per cent plant mortality and larval mortality along with larval weight gain were recorded.

In the fourth set ten grubs weighing 2500 to 2700 mg were released 40 DAS and these were sampled 10 days later (50 DAS). The per cent plant mortality and larval mortality along with larval weight gain were recorded for this set also. This staggered release of the grubs was done to simulate the conditions in field where grubs of different ages feed on the roots and to see the effect of seed treatment on them.

Effect of these chemicals on the incidence of sucking pests and the leafminer population was also recorded 60 DAS. The number of leafminer larvae were counted in 5 randomly selected plants/plot. To record the leaf damage by leafminer 30 leaves/plot were plucked and area was measured with a leaf area meter.

3.3.3.1. Seed Pelleting

The purpose of this experiment was to develop an effective seed pelleting (coating) technique which would retain the insecticide for a longer time. Different adhesives like rice

gruel, commercial starch REVIVE and gum arabic in different concentrations were tried to select the best adhesive and best concentration. .Gypsum generally used in groundnut cultivation was alone used in different quantities as binding material to select the appropriate quantity of the binding material.

For this purpose 100 g of groundnut kernels were used for each treatment and for each concentration of the test material. The materials used were 10 ml of rice gruel (obtained from normally cooked rice), 10 ml of 20%, 27% and 32% Gum arabic and 5% starch (REVIVE). Among these materials 27% gum arabic was found to be the best and was selected as an adhesive to the groundnut kernels. Gypsum sieved with an 80 mesh sieve was used at 9 g, 12 g and 18 g per 100 g gum arabic (27%) coated seeds. Gypsum @ 12 g $100g^{-1}$ gum arabic coated seeds found to be the best and was used for the seed pelleting technique in this experiment.

Seed pelleting was done by first coating with a known concentration (27%) of adhesive, followed by the appropriate concentration of insecticide and lastly with gypsum @ 120 g kg^{-1} kernels.

3.3.3.2. Germination Test

To see the germination % of the formulated seed pellet an experiment was conducted in the lab. Ten pelleted seeds, insecticide treated seed and untreated seed were sown in ten pots each and the germination % was noted after 10 days.

3.4 RESIDUE ANALYSIS

Studies on the pesticide residues present in soil, seed, seedlings and haulms of groundnut following seed treatment with chlorpyriphos 20EC were carried out separately in the alfisol at IAC in the rainy season of 1995-96. The trail was laid in RBD in 4x4m plots

in RP-7A. No crop was sown in the previous season in the selected field.The treatments used were chlorpyriphos 20 EC @ 6, 12.5 and 25 ml kg^{-1} seed along with an untreated control. These were replicated 5 times. Groundnut seed was put in a seed treating drum and was dressed with the doses of insecticide given above and shade dried 12 hours before sowing. The variety used was ICGS-44 and all the recommended agronomic practices were followed. Soil and seedling samples for residue analysis were taken on 0, 5, 10, 20 days after sowing and seed and haulm samples at harvest. The sampling and processing of the material for residue analysis are as follows.

3.4.1. Sampling

Soil samples from all the treatments were drawn from 6-8 places in each plot with a soil core. The samples from each plot (replicate) were mixed thoroughly and a sample of 50 g was taken by quartering and analysed. Seedlings from the spots utilised for soil sampling were uprooted, collected and used for analysis. From the harvested produce 100 g of kernel and haulms were collected from each plot at harvest. These were finely chopped in a blender. A subsample of 50 g from each plot was subsequently analysed.

3.4.2. Extraction, clean up and estimation

The soil, seed, seedling and haulm samples (50 g) were separately blended with 150 ml acetonitrile. After allowing for 24 hr, the extract was filtered and reextracted with acetonitrile. The acetonitrile layers were combined and concentrated in a rotary vacuum evaporator over a water bath to about 20-25 ml. The acetonitrile layer was transferred to a 1 L separating funnel and diluted with 250 ml of 5% aqueous sodium chloride and partitioned into (3 x 50 ml) n-hexane. This extract was passed through anhydrous sodium sulphate and concentrated to near dryness. This was dissolved in 10 ml n-hexane for adsorption chromatography. A glass column was packed with 2 g anhydrous sodium

sulphate, 20 g silica gel and 2 g anhydrous sodium sulphate upward and prewashed with 50 ml hexane. The extract was transferred to the glass column and eluted with 150 ml 5% ethyl acetate in n-hexane. This was concentrated to 50 ml and the pesticide residue estimated by gas chromatography (GC) (Indian Standard Method, IS:12365, 1988). The GC had the following parameters.

GC	:	Fisons 8000
Detector	:	Electron Capture Detector
Column	:	SE - 30
Oven temperature (^{0}C)	:	200
Detector temperature	:	250
Injector temperature	:	250
Carrier gas flow (ml min^{-1})	:	60
Retention time (min)	:	2.17
Sensitivity	:	0.01 µg/g

RESULTS

CHAPTER IV

RESULTS

4.1 WHITE GRUB SPECIES OF MAJOR GROUNDNUT GROWING AREAS OF ANDHRA PRADESH

The surveys of major groundnut growing areas of Andhra Pradesh and also light trap collections at ICRISAT during rainy seasons of 1995 and 1996 have shown the occurrence of 14 species belonging 6 genera of the sub-family Melolonthinae and 14 species belonging to 2 genera of the sub-family Rutelinae. The species were identified based on the male genitalia and other morphological characters of the adults. A list of the species collected, place of collection and source of collection are presented in Tables 5 and 6.

Melolonthinae:

Apogonia spp., A. ferruginia Fabricius, *Autoserica spp., Brahmina mysorensis* Frey, *Holotrichia reynaudi* Blanchard, *H. rufoflava* Brenske, *H. serrata* Fabricius, *Maladera spp., Schizonycha decipiens* Arrow, *S. fuscescens* Blanch. *S. ruficollis* Fabricius were the species of melolonthinae collected from the groundnut growing tracts (Plate 2 and 3).

Rutelinae:

Only two genera viz., *Adoretus and Anomala* were predominant from the sub-family rutelinae (Plate 4 and 5). The species recorded were *Adoretes bicolor* Brenske, *A. decanus* Oh., *A. duvanceli* Bl., *A. lasiophagus, A. stolicykae* Oh., *A. versuts* Harold, *Adoretes spp., Anomala bengalensis* Bl., *A. dorsalis* var *Fraterna* Fet., *A. dorsalis* Fabr., *A. ruficapilla* Burm., *A. varicolor* Gyll were the species of rutelinae found from the collections of groundnut growing areas.

Table 5. White grub adult species collected on different hosts in the groundnut ecosystem of Andhra Pradesh during rainy season, 1995.

White grub spp.	Place of collection	Host(s) / light trap
Sub family: Melolonthinae		
Apogonia sp. 1	ICRISAT	Acacia, Ber,
	Gooty (A)	Neem, Light Trap
Apogonia sp.2	ICRISAT	Acacia
	Gooty(A)	Ber
	Pebberu(K)	Neem, Light Trap
Holotrichia	ICRISAT	Acacia, Ber,
reynaudi Blanch.	Garledinne (A)	Sigara
	Hampapuram (A)	
	Lolur, Gooty (A)	
	Papili (K)	
	Dhone (K)	
	Pebberu (K)	
	Wanaparthi (M)	
	Renigunta (C)	
	Rangampet (C)	
Holotrichia	ICRISAT	Sigara
rufoflava	Rangampet (C)	Ber
Brenske	Renigunta (C)	Neem
Holotrichia	ICRISAT	Neem
serrata Hope	Lolur (A)	Ber
	Papili (K)	
Schizonycha	Pebberu (K)	Ber
decipiens Arrow		
S. fuscescens	Lolur (A)	Neem
Blanch	Renigunta (C)	Ber
S. ruficollis	ICRISAT	
	Hampapuram (A)	Ber
	Lolur (A)	Neem
	Garladinna (A)	

White grub spp.	Place of collection	Host(s) / light trap
Maladera sp.1	ICRISAT Hampapuram (A) Lolur (A)	Ber, Neem
Maladera sp.2	ICRISAT	Light trap
Sub - family: Rutelinae		
Adoret s *bicolor* Brenske	ICRISAT Lolur (A) Hampapuram (A) Renigunta (C)	Ber, Neem
A. versutus Harold	Pebber(K)	Ber
Adoret·s sp	ICRISAT	Light trap
Anomala *bengalensis Bl.*	ICRISAT	Light trap
A dorsalis Fabr.	Hampapuram (A)	Ber
A varicolor Gyll.	ICRISAT	Light trap

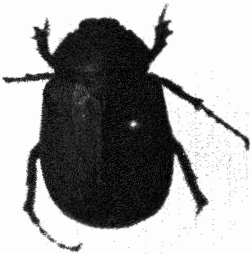
A = Ananthapur; C = Chittoor; K=Kurnool; M = Mahaboobnagar

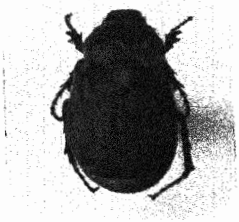
Table 6. White grub adult species collected on different hosts in the groundnut ecosystem of Andhra Pradesh during rainy season, 1996.

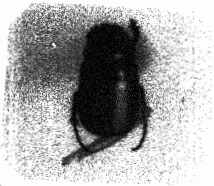
White grub spp.	Place of collection	Host(s)/ Light trap.
Sub family: Melolonthinae		
Apogonia ferruginia (F.)	ICRISAT Tirupathi (C)	Puttur (C) Acaci Drumstick Light trap
Apogonia sp.	ICRISAT	Acacia, drumstick, Light trap
Autoserica sp. 1	Puttur (C) ICRISAT	Neem Light trap
Autoserica sp. 2	Puttur (C)	Neem
Brahmina mysorensis Frey.	Puttur (C) Chittoor	Acacia Neem, Ber
Holotrichia reynaudi Bl.	Puttur, (C) Kurnool Chittoor, Hampapuram (A) Gooty (A) ICRISAT	Acacia Ber
H. rufoflava	Puttur (C)	Neem
H. serrata	ICRISAT Puttur (C) Rangampet (C) Veldhurthy (K)	Acacia Light trap
Schizonycha decipiens	Puttur (C)	Acacia, Neem
S. fuscescens Bl.	Puttur (C)	Acacia
S. ruficollis F.	Puttur (C) ICRISAT Rangampet (C) Tadipatri (A)	Acacia Ber

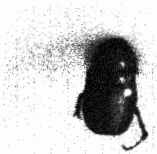
White grub spp.	Place of collection	Host(s)/ Light trap.
Sub family. Rutelinae		
Adoretus bicolor Br.	Puttur (C) Kurnool (K) ICRISAT	Acacia Ber Light trap
A. decanus Oh.	ICRISAT	Ber, Light trap
A. duvanceli Bl.	ICRISAT	Light trap
A. lasiophagus	ICRISAT	Light trap
A. stoliczkae Oh.	ICRISAT	Light trap
A. versutus Harold	ICRISAT	Light trap
Adoretus sp. 1	Rangampet (C)	Acacia
Adoretus sp. 2	ICRISAT	Light trap
Anomala bengalensis Bl.	ICRISAT	Light trap
A. dorsalis Var *fraterna* Fab.	Anantapur, ICRISAT	Light trap
A. dorsalis Fab.	ICRISAT	
A. ruficapilla Burm.	ICRISAT	Acacia & Light trap

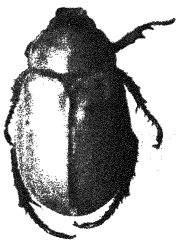
A = Ananthapur; **C** = Chittoor; **K**=Kurnool











From the adults collected during 1995 and 1996 seasons, *Holotrichia reynaudi* was found to be the predominant species collected from all the major groundnut growing areas of Andhra Pradesh. *H. serrata* mostly found in the ICRISAT farm and *Schizonycha ruficollis* from ICRISAT, Ananthapur and Chittoor districts were the other two important species associated with groundnut. The species-wise occurrence, place of predominance and their common hosts on which they were predominant are as follows:

4.1.1 *Holotrichia* spp

Holotrichia reynaudi was the most abundant species found in most of the important groundnut growing tracts of Andhra Pradesh and constitutes around 90-95 per cent population of white grub adults during both 1995 and 1996 seasons. These were collected from all the major groundnut growing districts viz., Ananthapur, Kurnool, Chittoor and Mahboobnagar.

H. reynaudi was collected from Garledinne, Hampapuram, Lolur and Gooty of Ananthapur district; Papili, Dhone and Pebberu of Kurnool district, Renigunta and Rangampet of Chittoor district, Wanaparthy of Mahaboobnagar district and ICRISAT farm. The adults of *H. reynaudi* were only found feeding on Acacia *(Acacia arabica),* ber *(Zizyphus jujuba* and *Zizyphus sp.)* and Sigara.

Holotrichia serrata was another species of white grub collected in large populations from ICRISAT and to a little lesser extent from other groundnut growing areas. The adults were collected from Lolur of Ananthapur district, Papili and Veldhurthy of Kurnool district, Puttur and Rangampet of Chittoor district. These were found feeding on neem, ber, and Acacia.

H. rufoflava was the other species collected from Rangampet, Renigunta and Puttur groundnut growing areas of Chittoor district and ICRISAT farm on neem, ber,and sigara.

4.1.2 *Schizonycha* spp

Schizonycha ruficollis was another species of melolonthids which was found to be relatively more abundant in the adult collections. It was observed in the collections from Hampapuram, Lolur, Garladinne, Tadipatri of Ananthapur district; Puttur and Rangampet of Chittoor district and ICRISAT farm. They were found feeding on ber, neem and Acacia.

The other species recorded were *S. decipiens and S. fuscescens* which were found in less numbers at Pebberu (Kurnool district), Lolur (Ananthapur district) Puttur and Renigunta (Chittoor district). Acacia, neem and ber were the principal trees on which these were found feeding.

4.1.3. Other Melolonthids

Apogonia spp., Autoserica spp. and the lone species *Brahmina mysorensis* were among the melolonthids of minor importance found in very less numbers in Chittoor district, ICRISAT farm and Gooty (Anantapur district) on Acacia, ber, neem, drumstick and light trap at ICRISAT.

4.1.4. *Anomala* spp.

The species viz., *Anomala bengalensis, A.. dorsalis, A.. varicolor* and *A.. ruficapilla* are the rutelinids collected from light trap of ICRISAT. The adult beetles of *A.. dorsalis* defoliating ber have been found only at Hampapuram of Ananthapur district and the food plants of others were not ascertained in the present studies.

4.1.5 *Adoretus* spp.

Among the *Adoretus spp., A.. bicolor* and *A.. versutus* and other unidentified species have been found feeding on ber, neem and Acacia. Rest of the species were the collections of light traps at ICRISAT. In general, these are of minor importance as defoliators.

4.1.6 Area-wise distribution of white grub species

It is evident from the results of 1995 season (Table 5) *Holotrichia reynaudi* was the predominant species in all groundnut growing areas in the districts of Ananthapur, Kurnool, Chittoor and Mahboobnagar (Fig. 2). *H. serrata* was mostly found on the IAC farm. Among the three species of *Schizonycha, S. ruficollis* was commonly observed in all the areas. *S. decipiens* is the first report from peninsular India.

The collections from Ananthapur consisted of melolonthids like *H. reynaudi, H. serrata, S. fuscescens, S. ruficollis* and *Maladera* spp. and rutelinids like *Adoretus bicolor, Anomala dorsalis. H. rufoflava* was found at ICRISAT and also in Chittoor. *S. fuscescens,* a melolonthid and *A.. bicolor* a rutelinid were also recorded from Chittoor.

Apart from two species of *Holotrichia, S. decipiens,* a rare specimen was identified in the collections of Kurnool. *Adoretes versutus* was also recorded from Kurnool only.

Holotrichia reynaudi was the only species recorded from Mahboobnagar. Except *S. fuscescens, S. decipiens, Adoretus versutus* and *Anomala dorsalis* all others were observed at ICRISAT farm.

The survey for beetles in the rainy season of 1996 also confirmed the predominance of *H. reynaudi, H. serrata,* and *S. ruficollis* in Ananthapur, Chittoor, Kurnool and ICRISAT farm. S. *fuscescens* and *S. decipiens* were mostly recorded from Puttur of Chittoor district. *Apogonia ferruginia, Brahmina mysorensis, Autoserica* spp. and

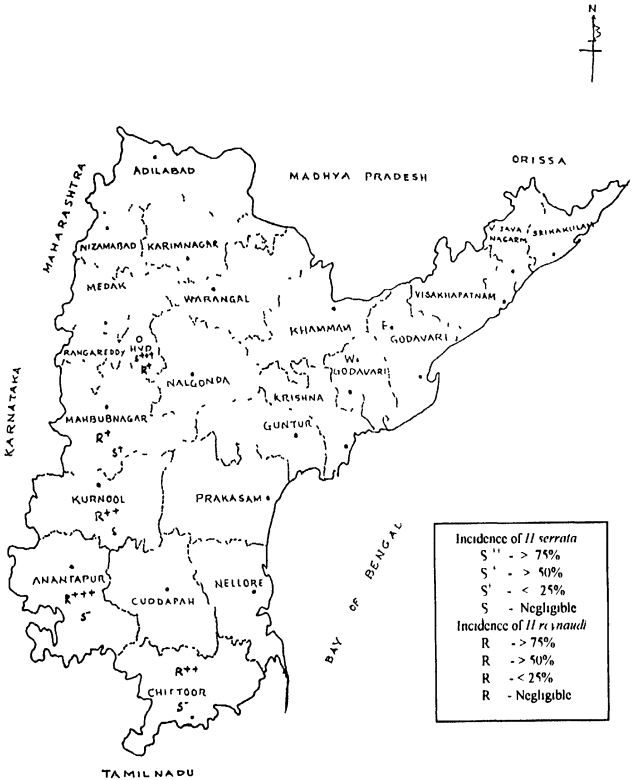


FIG -2 DISTRIBUTION AND INTENSITY OF INCIDENCE OF *H.serrata* and *H.reynaudi* IN THE GROUNDNUT GROWING AREAS OF ANDHRA PRADESH

Adoretes bicolor added to the 1995 seasons collection from Chittoor district. Most of the rutelenids were from the ICRISAT light trap collections (Table 6).

4.1.7 Host plants

The adults of root grub species have been found feeding at night on the foliage of Acacia *(Acacia arabica),* ber *(Zizyphus jujuba, Zizyphus* sp.), neem *(Azadirachta indica),* sigara (Vernacular name) and drum stick *(Moringa oleifera).* These plants in the groundnut growing areas which are present as avenue trees were found completely defoliated during the rainy season when the adults are active.

Distinct host preferences have been observed by the adults of predominant species of white grubs. *Holotrichia reynaudi* which is the most predominant species was collected principaly on ber (Plate 6) and Acacia and only negligible numbers were collected from neem (Table 7). Similarly very less numbers were found feeding on drum stick. *H. serrata* was collected only from neem and rarely from Acacia. *Schizonycha ruficollis* was mostly found on Acacia and ber. Very few adults of this species have been collected from neem. Most of the rutelinids were collected from light traps at ICRISAT and few species from the ber plants.

4.1.8 Grubs feeding on groundnut

The grubs collected from the groundnut fields in Ananthapur, Kurnool, Chittoor and Mahboobnagar in the rainy seasons of 1995 and 1996 were reared to adults in nethouses at ICRISAT. Out of 250 grubs collected from groudnnut fields of Ananthapur 215 emerged as adults. From Kurnool, out of 96 field collected grubs, 75 were reared into adults. Similarly out of 110 grubs reared only 70 resulted into adults from groundnut fields

Table 7 Common host plants of economically important species of white grub adults found feeding in groundnut growing areas of Andhra Pradesh

White grub species	Preferred host trees			
	Ber	Neem	Acacia	Drum stick
Holotrichia reynaudi	+++	+	++	+
H serrata	-	+++	+	-
Schizonycha ruficollis	++	+	+++	-

+++ = High ++ = Moderate + = Low - = Nil

PLATE 6: [illegible]

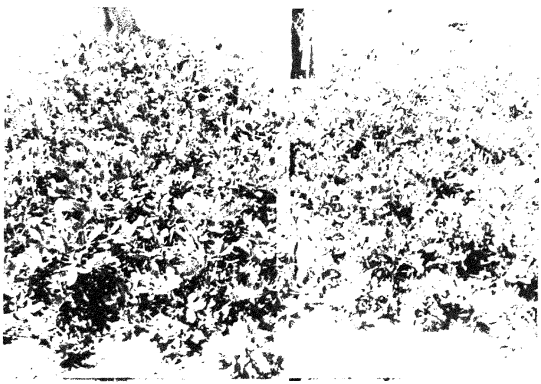


PLATE 7: [illegible]

of Chittoor. Only 20 adults emerged from 35 grubs collected from Mahboobnagar. All the adults which emerged from these collections were identified as *Holotrichia reynaudi.*

These grubs were found feeding on the groundnut roots and caused wilting and mortality of plants. Several smaller grubs which were collected from groundnut fields in Ananthapur and Kurnool in the rainy season of 1996 contitnued to be in grub stage, probably hibernating as grubs for a longer peroid. Hence these could not be identified. However, these smaller grubs were not found to cause mortality of plants though they were found associated with the crop.

4.2 LIFE CYCLE OF *Holotrichia reynaudi*

The life cycle of *Holotrichia reynaudi* was studied in the laboratory at a temperature of 27°C and relative humidity of 60%. The mating pairs collected from Ananthapur have been utilised for studying life cycle. The morphological parameters and the duration of each stage was recorded and the results are presented in the following Table 8.

4.2.1 Egg Stage

Beetles were found to lay eggs in batches of two in the moist loose sand in the oviposition cages. Egg was pearly white, cylindrical when freshly laid and measures on an average 3 mm in length and 1.78 mm in breadth. After 5 to 6 days the egg turns almost spherical, smooth measuring 2.96 mm in diameter and 3.67 mm in length (Table 8). When the egg nears hatching, the chorion becomes slightly transparent towards one end and milky white towards the other end and the developing embryo is visible with its cephalic appendages. The incubation period under laboratory conditions ranged from 11 to 12 days

(Table 8). Egg laying mostly done during day time. A maximum of four eggs were laid by a female in one day under laboratory conditions. Egg laying were irregular, sometimes leaving 3 to 5 days gap between two egg laying days. These field collected adults extended their egg laying over 3 weeks in some individuals, majority of females laid more than 50 per cent of their eggs in the first 7 days after collection.

4.2.2 Grub stage

Immediately after hatching the neonate grub was creamy white in colour and measured on an average 14.9 mm in length and 3.5 mm in breadth with a head capsule width of 2.1 mm before moulting (Table 8). The head turns brown in few hours and the grubs became active in about 4 to 5 hours. The first instars were kept in petri dishes filled with sand and organic matter. They were found to survive on the organic matter. The average duration of first instar grub was 15-16 days.

The second instar grub is dirty white in colour and measured 21.7 mm in length, 5.5mm in breadth and the head capsule width being 3.1 mm. These were transferred into plastic dishes with pearl millet seedlings and the grubs started actively feeding on the roots and rootlets of pearl millet. The shape and colour resembles the first instar but the last abdominal segment becomes more swollen and darker. The duration of second instar on an average was 17.5 days, the minimum and maximum being 15 and 20 days respectively (Table 8).

The third instar is dirty white in colour, measuring on an average 40.6 mm in length, the head capsule is 5 mm in width. The third instar is an active root feeder, with powerful mandibles. The thoracic segments are distinct, the fore legs shorter, the hind legs longer and the middle pair in between. The average duration of the third instar was 34 days, the minimum and maximum duration being 33 days and 35 days respectively. The average total grub period was 67 days (Table 8).

Table 8. Morphometrics and duration of egg, grub and pupal stages of *H. reynaudi*

Stage	Size			Duration (days)
	Length (mm)	Width (mm)	Head capsule (mm)	
Egg				
Freshly laid	3.00	1.78	-	11.5 (11-12)
Before hatching	3.67	2.96	-	
Grub				
1st instar	14.90	3.50	2.1	15.5 (15-16)
2nd instar	21.70	5.50	3.1	17.5 (15-20)
3rd instar	40.60	8.50	5.0	34.0 (33-35)
Pupa	21.00	8.50	-	17.0 (15-19)
Egg to adult				96.0 (89-102)

Values in parenthesis are ranges

4.2.3 Pupal stage

The 3rd instars grew to their full size in September and by first week of October and before pupation they burrowed deeper into the soil to the bottom of the jar and formed an earthen cell in which they lay in a semicircular fashion. The average pupal period was around 17 days. The pupa was dirty white in color. The pupa was exarate and it measured on an average 21 mm long and 8 to 9 mm in width . The pupal period ranged 15 to 19 days under laboratory conditions. Pupa did not survive when the earthen cell was damaged.

4.2.4 Adult stage

The adults eclosed from the pupae in October/November. The elytra of freshly emerged beetles was brick red in colour which slowly turned to dark brown in a month's time. The abdomen of the freshly emerged beetles was pearly white unlike the dirty white of the old beetles. Though the beetles were left to mate in the oviposition cages, they did not feed and died after a few weeks. The total life cycle from egg to adult was completed in 96 days on an average (Table 8).

4.3. CHEMICAL CONTROL OF WHITE GRUBS BY SEED TREATMENT

Two experiments were conducted during 1995 and 1996 rainy seasons to evaluate the efficacy of chlorpyriphos and imidacloprid as seed treatment chemicals against the grubs of *Holotrichia serrata*. The results are presented in Tables 9, 10, 11, 12 and 13 .

4.3.1. Efficacy of the seed treatment chemicals against root grub during 1995 season

In the rainy season of 1995, imidacloprid 70 WS @ 5 g and 10 g kg^{-1} seed and chlorpyriphos 20 EC @ 6 and 12.5 ml kg^{-1} seed were tested as seed treatment chemicals against the grubs of *Holotrichia serrata* in the specially designed microplots under field conditions. Percent plant mortality, percent larval mortality and larval weight gain were taken into account to assess the efficacy of the seed treatment chemicals and the data are presented in Table 9.

4.3.1.1 Plant mortality : No significant differences in the plant mortality caused by grubs were observed between the treatments. The plant mortality percentages ranged between 1.3 to 6.0 between the treatments. In general the higher doses of imidacloprid and chlorpyriphos recorded relatively lower plant mortality than the lower doses (Table 9). As expected the percent plant mortality was found to be high (13.3) in the untreated control.

4.3.1.2 Larval mortality : The recommended and higher doses of imidacloprid and chlorpyriphos gave significantly high mortality of the grubs compared to untreated control. The percentage mortalities observed at 20 DAS ranged between 66 to 90 in the treated plots (Table 9). Both the chemicals were found to be equally effective in controlling the grubs. Among the doses, higher doses, in both chemicals caused relatively more grub mortality than the recommended doses. However, imidacloprid at the recommended dose (5 g kg^{-1} seed) recorded only 66% mortality of grubs against 85% mortality in the higher dose and 85 to 90% mortality in both the recommended and higher dose of chlorpyriphos. Mortality of grubs to the extent of 27% was observed even in untreated control.

Table 9. Effect of different doses of chlorpyriphos and imidacloprid applied as seed dressing chemicals against grubs of *H. serrata* at 20 DAS (rainy season, 1995).

Treatment	Plant mortality (%)	Larval mortality (%)	Larval wt gain (mg)
Imidacloprid 5 g kg^{-1} seed	3.3	66.0	-13
Imidacloprid 10 g kg^{-1} seed	1.3	85.0	-91
Chlorpyriphos 6 ml kg^{-1}seed	6.0	85.0	106
Chlorpyriphos 12.5 ml kg^{-1}seed	4.0	90.0	113
Control	13.3	27.0	393
SE(m)	2.92	4.79	6.4
CD at 5%	7.86	14.37	18.9

Number of grubs released	20
Mean weight of each grub (mg)	200

4.3.1.3 Larval weight gain : It is evident from the data that there is significant reduction in larval weight gain inall the treatments compared to control at 35 DAS. In both doses of imidacloprid, there was a negative larval weight gain. Between the two doses of chlorpyriphos there was no significant difference in the larval weight gain and the weight gain was 106 and 113 mg compared to 393 mg in the untreated control (Table 9).

4.3.2 Efficacy of seed treatment chemicals against root grub during 1996 rainy season:

In the rainy season 1996, the effective dose (6 ml kg^{-1} seed) of chlorpyriphos was pelleted with gypsum and its efficacy was assessed in comparison with same dose of chlorpyriphos and effective dose of imidacloprid (5g kg^{-1} seed) both applied as seed dressers without pelleting in micro-plots. The efficacy was evaluated at 20, 30, 40 and 110 days after sowing in separate experiments and the data on plant mortality, larval mortality larval weight gain and pod yield are presented in Tables 10-13. In addition, data on the effect of these chemicals on the groundnut sucking pest complex (jassids, thrips) and leaf miner also recorded and presented separately in Table 15.

4.3.2.1 Efficacy at 20 days after sowing:

4.3.2.1.1 Plant mortality: Though the percent plant mortality was low in all the treatments, (0-4.7%), there were significant differences between the treatments. The untreated control recorded the highest plant mortality of 4.7%. The percent plant mortality in micro plots treated with chlorpyriphos 6 ml kg^{-1} seed and chlorpyriphos seed pellet and imidacloprid at 5 g kg^{-1} seed were 1.3, 0.7 and 0 respectively which was significantly less than the untreated control (Table 10). There was no significant difference in the plant mortality caused by the grubs between the three chemical treatments. However, imidacloprid treated plots recorded no plant mortality at all (Plate 7).

Table 10. Efficacy of chlorpyriphos seed pelleting in comparison with chlorpyriphos and imidacloprid applied as seed dressing chemicals against grubs of *H. serrata* at 20 days after sowing (rainy season, 1996).

Treatment	20 Days after sowing		
	Plant mortality (%)	Larval mortality (%)	Larval wt. gain (mg)
Chlorpyriphos (6 ml kg^{-1}seed)	1.3 (0.73)	72.0	-38
Chlorpyriphos 6 ml + Gum arabic + Gypsum (seed pellet)	0.7 (0.38)	90.0	-40
Imidacloprid (5 g kg^{-1} seed)	0.0 (0.00)	56.0	-78
Control	4.7 (1.91)	6.0	348
SE(m)	0.78 (0.334)	5.61	2.80
CD at 5%	(1.02)	17.30	8.50

Number of grubs released	10
Mean weight of each grub (mg)	350

*Values in parentheses are square root transformed values.

4.3.2.1.2 Larval mortality : The data on percent larval mortality shows that the larval mortality recorded in chlorpyriphos 6 ml kg^{-1}, chlorpyriphos seed pellet and imidacloprid 5 g kg^{-1} treated plots was significantly higher than the untreated control (Table 10). Among the treatments, chlorpyriphos seed pellet caused highest percent larval mortality (90) when compared to chlorpyriphos 6 ml and imidacloprid 5 g kg^{-1} seed. Even though the percent larval mortality caused by chlorpyriphos 6 ml was high (72%) compared to imidacloprid 5 g kg^{-1} seed (56%) both were on par.

4.3.2.1.3 Larval weight gain : Larval weight reduction was observed in chlorpyriphos seed dressing, chlorpyriphos seed pellet and imidacloprid treated plots when compared to control (Table 10). The larval weight gain was highest in untreated control (348 mg). Among the chemical treatments the negative larval weight gain was more or less similar and there was no significant differences between them.

4.3.2.2 Efficacy at 30 days after sowing

4.3.2.2.1 Plant mortality: The percent plant mortality ranged from 13.3 to 0 in the untreated control and the treated plots. Imidacloprid 5 g kg^{-1} treated plots recorded no plant mortality and chlorpyriphos seed pellet treated plots had 3.3% plant mortality which was significantly lower than control (Table 11). Between the chlorpyriphos seed pellet treatment and chlorpyriphos seed dressing treatment no significant difference was observed and the plant mortality was 5.3 and 3.3 respectively. The plots where the seeds were dressed with chlorpyriphos at 6 ml kg^{-1} seed recorded 5.3% plant mortality but the mortality was significantly lower than the control which recorded 13.3% plant mortality (Table 11).

Table 11. Efficacy of chlorpyriphos seed pelleting in comparison with chlorpyriphos and imidacloprid applied as seed treatment chemicals against grubs of *H. serrata* at 30 days after sowing (rainy season, 1996).

Treatment	30 Days after sowing		
	Plant mortality (%)	Larval mortality (%)	Larval wt.gain (mg)
Chlorpyriphos (6 ml kg^{-1}seed)	5.3 (2.03)	84.0	56
Chlorpyriphos 6 ml + Gum arabic + Gypsum (seed pellet)	3.3 (1.10)	96.0	-152
Imidacloprid (5 g kg^{-1} seed)	0.0 (0.00)	50.0	-116
Control	13.3 (3.43)	18.0	584
SE(m)	2.21 (0.428)	7.75	9.74
CD at 5%	(1.31)	23.88	30.00

Number of grubs released 10
Mean weight of each grub (mg) 1000

' Values in parentheses are square root transformed.

4.3.2.2.2 Larval mortality : All the three chemical treatments i.e., chlorpyriphos at 6 ml kg^{-1} seed, chlorpyriphos seed pellet and imidacloprid at 5g kg^{-1} seed caused significantly higher larval mortality than untreated control. Highest percent of larval mortality (96%) was observed in the chlorpyriphos seed pellet followed by chlorpyriphos seed dressing (84%). Imidacloprid at 5g kg^{-1} seed recorded 50% larval mortality at 30 DAS (Table 11).

4.3.2.2.3 Larval weight gain

The highest larval weight gain was observed in untreated control (584 mg). Though there was a weight gain of 56 mg of grubs in chlorpyriphos 6 ml kg^{-1} seed, this was significantly less than the untreated control (Table 11). A negative larval weight gain was observed in chlorpyriphos seed pellet and imidacloprid 5 g kg^{-1} seed treated plots. There was no significant difference between these two chemical treatments in larval weight gain.

4.3.2.3 Efficacy at 40 days after sowing

4.3.2.3.1 Plant mortality : The plant mortality percentages were relatively low ranging from 0.0 to 4.4 in all the plots with chlorpyriphos and imidacloprid treated seeds compared to untreated control which recorded 15.7%.(Table 12)

4.3.2.3.2 Larval mortality : The highest percent larval mortality was observed in chlorpyriphos 6 ml kg^{-1} seed and chlorpyriphos seed pellet treated micro plots (92 and 96% respectively) (Plate 8a) at 40 DAS and was significantly higher than imidacloprid and untreated control (Table 12). It is evident from the data that percent larval mortality was more or less similar in imidacloprid 5 g kg^{-1} seed and untreated control (34 and 28% respectively) indicating that seed treatment with imidacloprid may not last longer to be effective against the root grubs in the soil to cause mortality.

PLATE 8 GRUBS FROM (a) UNTREATED AND (b) IMIDACLOPRID AND CONTROL PLOTS

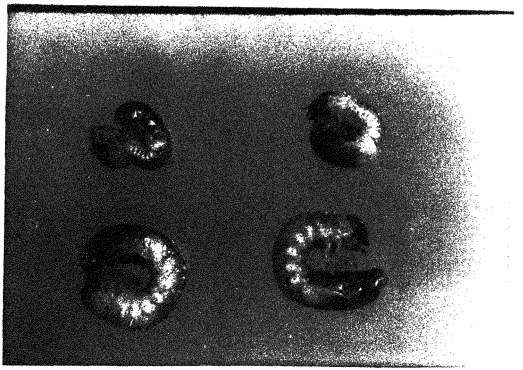


PLATE 9 GRUBS FROM (a) IMIDACLOPRID and (b) CONTROL PLOTS

Table 12. Efficacy of chlorpyriphos seed pelleting in comparison with chlorpyriphos and imidacloprid applied as seed dressing chemicals against grubs of *H. serrata* at 40 days after sowing (rainy season, 1996).

Treatment	40 Days after sowing		
	Plant mortality (%)	Larval mortality (%)	Larval wt. gain (mg)
Chlorpyriphos (6 ml kg^{-1}seed)	2.2 (1.14)	92.0	776
Chlorpyriphos 6 ml + Gum arabic + Gypsum (Seed pellet)	4.0 (1.46)	96.0	98
Imidacloprid (5 g kg^{-1} seed)	0.0 (0.0)	34.0	-178
Control	15.7 (3.24)	28.0	679
SE(m)	4.53 (0.659)	5.08	8.5
CD at 5%	NS	15.65	26.2
Number of grubs released	10		
Mean weight of each grub (mg)	2600		

* Values in parentheses are square root transformed.

4.3.2.3.3 Larval weight gain: The grubs in chlorpyriphos 6 ml kg^{-1} treated and untreated control plots showed more or less similar larval weight gain (776 mg and 679 mg respectively).(Table 12) However, there was significant loss in weight gain by grubs in chlorpyriphos seed pellet treated plots. Interestingly, eventhough the larval mortality was similar to untreated control in the case of imidacloprid treated plots, the grubs recorded a negative larval weight gain (-l 78 mg) (Plate 8b and Table 12).

4.3.2.4 Efficacy at 110 days after sowing

4.3.2.4.1 Plant mortality: At harvest (110 DAS) lowest percent of plant mortality (2 to 4%) was observed in all the plots compared to untreated control (30.7%) (Table 13). There was no significant difference in percent plant mortality between chlorpyriphos 6 ml kg^{-1} , chlorpyriphos 6ml kg^{-1} seed pellet and imidacloprid 5 g kg^{-1} seed treated micro-plots.

4.3.2.4.2 Pod yield : Mature pod weight recorded at 110 DAS from the plots planted with the seed treated with chlorpyriphos 6 ml kg^{-1}, chlorpyriphos seed pellet and imidacloprid 5 g kg^{-1} seed was two to three times high compared to control (Table 13). The pod yield was lowest in the untreated control (56 g/0.7 m^2) where as it ranged from 119 g to 191 g/0.7 m^2 in the plots sown with insecticide treated seed which was significantly higher than the control. The pod yield was observed to be highest in imidacloprid (191 g/0.7 m^2) followed by chlorpyriphos seed pellet (160 g/0.7 m^2) treated plots. Between the two treatment of chlorpyriphos treated plots, chlorpyriphos seed pellet recorded significantly higher yield (160 g/0.7 m^2) than chlorpyriphos 6 ml kg^{-1} seed treatment (119 g/0.7 m^2). (Table 13)

Table 13. Efficacy of chlorpyriphos seed pelleting in comparison with chlorpyriphos and imidacloprid applied as seed dressing chemicals against grubs of *H. serrata* at 110 days after sowing (rainy season, 1996).

Treatment	110 Days after sowing	
	Plant mortality (%)	Mature pod weight (g/0.7 m)
Chlorpyriphos (6 ml kg^{-1})	4.0 (1.25)	119.0
Chlorpyriphos 6 ml + Gum arabic + Gypsum (seed pellet)	4.0 (1.46)	160.0
Imidacloprid (5 g kg^{-1} seed)	2.0 (1.10)	191.0
Control	30.7 (5.46)	56.0
SE(m)	2.92(0.629)	12.1
CD at 5%	(1.93)	37.28

Number of grubs released 10
Mean weight of each grub (mg) 350

* Values in parentheses are square root transformed.

4.3.3 Overall Efficacy

The efficacy of seed treatment chemicals viz., imidacloprid and chlorpyriphos at recommended doses in comparison with higher doses appears to be generally comparable and equally effective with respect to lower plant mortality and higher grub mortality during 1995 rainy season (Table 9). Similar were the results on the effect on larval weight gain. Hence only recommended doses of these chemicals were tried for periodical assessment of their efficacy during 1996.

The overall efficacy of imidacloprid at 5 g kg^{-1} seed and chlorpyriphos at 6 ml kg^{-1} seed applied as seed dresser and also as a seed pellet was consistent with regard to plant mortality, larval mortality and larval weight gain when assessed periodically at 20, 30, 40 and 110 days after sowing (harvest). The plant mortality percentage progressively increased from 4.7 to 30.7 in untreated controls compared to the seed treatment plots which ranged 0 to 5.3 (Table 14). Interestingly, except for 2% plant mortality, at harvest (110 DAS) imidacloprid recorded no mortality at 20, 30 and 40 DAS. Between the chlorpyriphos seed dressed and seed pelletted treatments the percent plant mortality was relatively lower or equal mostly in the later than in the former at 20, 30 and 110 DAS (Table 14).

The larval mortality was always highest and it ranged between 90-98% in the plots planted with chlorpyriphos seed pellets followed by chlorpyriphos applied as seed dressing chemical. The plot treated with imidacloprid recorded only 56 to 34 percent grub mortality. In general, progressive decrease in grub mortality was observed in imidacloprid treated plots from 54 to 50 to 34 at 20, 30 and 40 DAS (Table 14).

Larval weight gain was always negative throughout the period of assessment (20, 30 and 40 DAS) in the plots seeded with imidacloprid as seed dressing chemical. Larval weight gain was negative both at 20 and 30 DAS and positive with a minimum 98 mg

Table 14. Relationship between days after sowing and effect of seed treatment chemicals on plant mortality, larval mortality, larval weight gain and pod yield (Rainy season 1996).

Days after sowing	chlorpyriphos seed dressing (6 ml kg^{-1} seed)	chorpyriphos seed pellet (6 ml kg^{-1} seed)	Imidacloprid seed dressing (5 ml kg^{-1} seed)	control	SE(m)
		plant mortality (%)			
20	1.3 (0.73)	0.7 (0.38)	0.0 (0.0)	4.7 (1.91)	0.78 (0.334)
30	5.3 (2.03)	3.3 (1.10)	0.0 (0.0)	13.3 (3.43)	2.21 (0.428)
40	2.2 (1.14)	4.0 (1.46)	0.0 (0.0)	15.7 (3.24)	4.53 (0.659)
110	4.0 (1.25)	4.0 (1.46)	2.0 (1.10)	30.7 (5.46)	2.92 (0.629)
		Larval mortality (%)			
20	72	90	56	6	5.61
30	84	96	50	18	7.75
40	92	96	34	28	5.08
		Larval weight gain (mg)			
20	-38	- 40	-78	348	2.8
30	56	-152	-116	584	9.74
40	776	98	-178	679	8.5
		Mature pod yield (g/0.7 m^2)			
110	119	160	191	56	12.1

weight gain at 40 DAS with chlorpyriphos applied as seed pelleting chemical. Chlorpyriphos applied as a seed dressing chemical recorded negative weight gain of the grub only at 20 DAS, positive at 30 DAS and the positive weight gain was similar to untreated control at 40 DAS. The negative weight gain of the grubs was observed only at 20 DAS in both the chemicals applied either as seed dressing chemicals or chlorpyriphos applied as seed pelleting (Fig. 3).
(Table 14).

Good correlation was observed between the weight gain of the grubs and pod yields. Pod yields were highest (1 91 g/0.7 m^2) in the imidacloprid treatment which always had negative weight gain of the grub at all stages of periodical assessment (Table 14). Chlorpyriphos applied as a seed pellet also recorded a negative weight gain at both 20 and 30 DAS with a little positive weight gain at 40 DAS found to be next best after imidacloprid in recording the better yields (160 g/0. 7 m^2). Chlorpyriphos applied as seed dressing chemical which had an effect of negative weight gain of the grub only at 20 DAS recorded only the pod weight of 119 g/0.7 m^2 . The untreated control where the grubs recorded always positive weight gain recorded 2 to 3 folds lower pod yields (56 g/0.7 m^2) compared to the yields of treated plots (Fig. 4).

4.3.4 Effect of seed treatment chemicals on foliar pests of groundnut

Effect of seed treatment chemicals on the incidence of foliar pests of groundnut was assessed from the micro plots and the results are presented in Table 15.

The data recorded at 60DAS on the incidence of leaf miner clearly indicated that only imidacloprid applied at 5g Kg^{-1} seed checked the incidence. The leaf miner larvae

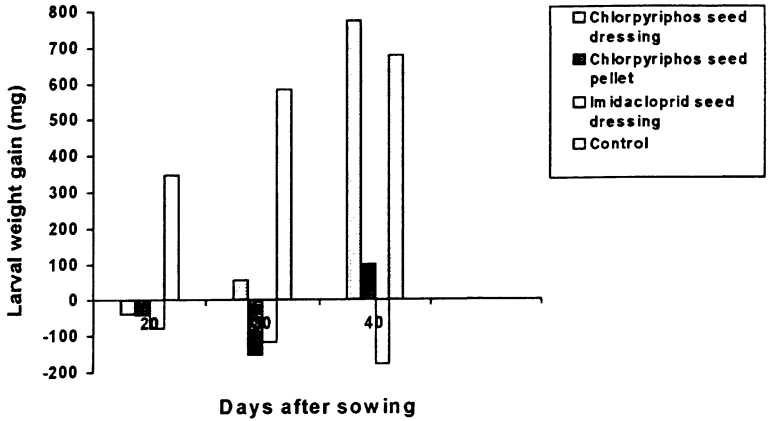


Fig. 3. Larval weight gain at 20, 30 and 40 DAS in chlorpyriphos seed dressed, chlorpyriphos seed pelleted and Imidacloprid seed dressed plots.

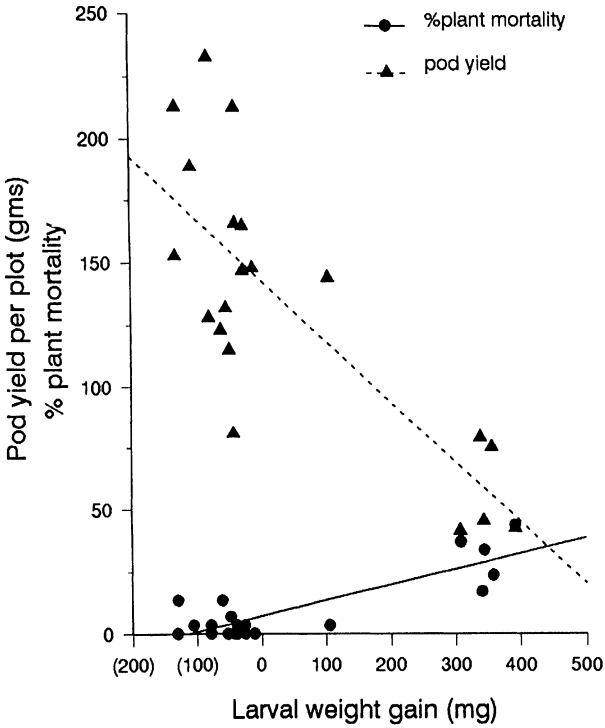


Fig 4 Relationship between percent plant mortality, pod yield and larval weight gain

were reduced to around 50 per cent in this treatment. Chlorpyriphos had no effect on the incidence of the leaf miner and was on par with control (Table 15).

None of the treatments had any effect on the incidence of jassids and thrips. Imidacloprid treatment recorded significantly highest leaf area (471 cm^2 /30 leaves) compared to chlorpyriphos and untreated control.

4.4. SEED PELLETING

Of the different adhesives viz., rice gruel (rice:water 1:2), 20%, 27% and 30% gum arabic and 5% commercial starch (REVIVE) tested as stickers, gum arabic proved to be the best adhesive. Of the three concentrations of gum arabic 27% was found to be the ideal concentration as 20% gum arabic was found to be too thin and 30% was found to be too thick in consistency and damaged the seed coat or testa of the Kernel. Gypsum sieved through 80, 100 and 200 mesh sieves were used as binders. Of these Gypsum of fine mesh obtained through 80 mesh sieve was found to be ideal as it formed a smooth coat over the gum arabic and chlorpyriphos coated seed. The final product of seed pellet coated with 27% gum arabic as a sticker to chlorpyriphos and 80 mesh gypsum powder was a free flowing groundnut seed masked by the white gypsum powder. Seed pelleting was done with 100 ml of 27% gum arabic for 1 kg groundnut seed followed by 6 ml chlorpyriphos and 120 g of 80 mesh gypsum powder. The seeds were shade dried and the process of seed pelleting was done 12 hrs. before sowing.

4.5. GERMINATION TEST

Germination counts were taken 10 days after sowing from untreated control, chlorpyriphos treated seed and gypsum coated seed pellet sown in 10 pots each. Per cent

Table 15. Effect of chlorpyriphos and imidacloprid seed treatment on the incidence of foliar and sucking pests of groundnut (rainy season, 1996)

Treatments	Leafminer larvae/ 5 plants*	Jassids/ 5plants	Thrips/ 10terminal buds	Leaf area/ 30 leaves (cm)
1. Chlorpyriphos 6 ml kg^{-1} seed	47.4	8.0	8.0	335
2. Gypsum seed pellet	51.4	3.0	9.8	373
3. Imidacloprid 5 g kg^{-1} seed	28.4	2.8	8.8	471
4. Control	51.4	3.4	9.0	354
SE(m)	5.81	1.49	2.12	25.1
'F' test		NS	NS	
CD (5%)	17.90			77.33

Replicates - 5
Samples collected 60 days after sowing.

germination was 81, 82 and 82 for chlorpyriphos coated seed, gypsum coated seed pellet and untreated control respectively. The differences were not significant.

4.6. CHLORPYRIPHOS RESIDUES

The residues of chlorpyriphos applied as seed dressing at 6, 12.5 and 25 ml kg^{-1} seed were estimated from the soil, seedlings at 0, 5, 10 and 20 DAS and in kernels and haulms at harvest and the results are presented in Table 16.

4.6.1. Residues in soil

At a dose of 6 ml kg^{-1} seed, the initial deposit on '0' day was 0.0339 ppm which decreased to 0.0271 ppm on the 5th day, 0.0222 in 10 days and to 0.017 ppm on the 20th day (Table 16) . At double the dose of chlorpyriphos i.e. 12.5 ml kg^{-1} seed the residues at '0' day were 0.0702 ppm which increased to 0.0950 ppm on the 5th day. In 10 days time the residues showed a decrease to 0.0351 ppm. On the 20th day the residues of chlorpyriphos in soil further decreased to 0.0176 ppm (Table 16).

When the seed was treated with 25 ml kg^{-1} seed of chlorpyriphos 20 EC, the initial deposit of 0.1314 ppm was on '0' day increased to 0.1723 ppm on the 5th day and thereafter decreased to 0. 0432 ppm on 10th day and 0. 0291 ppm on the 20th day.

In all the three doses of chemical used the residues in soil were well below the maximum residue limit (MRL) of 2 ppm. At a dose of 6 ml kg^{-1} seed the residues showed a gradual decrease from '0' day to 20th day. However, at the two higher doses of 12.5 ml and 25 ml kg^{-1} seed, the residues of chlorpyriphos increased from '0' day to 5th day and thereafter declined on the 10th and 20th days (Table 16).

Table 16. Residues of chlorpyriphos in soil, seedlings, kernels and haulms of groundnut following seed treatment (rainy season, 1995).

Days after treatment	Chlorpyriphos residues					
	6 ml kg^{-1} seed		12.5 ml kg^{-1} seed		25 ml kg^{-1} seed	
	PPM	SE	PPM	SE	PPM	SE
RESIDUES IN SOIL						
0	0.0339	0.00056	0.0702	0.00084	0.1314	0.01733
5	0.0271	0.00221	0.0950	0.00445	0.1723	0.01177
10	0.0222	0.00519	0.0351	0.00890	0.0432	0.00092
20	0.0170	0.00248	0.0176	0.00176	0.0291	0.00456
RESIDUES IN SEEDLINGS						
0	0.3661	0.10259	1.0440	0.09084	1.4077	0.01192
5	0.3589	0.00493	1.0168	0.06310	1.3986	0.03829
10	0.3427	0.01525	0.8966	0.03403	1.3839	0.10318
20	0.3389	0.00839	0.7649	0.02287	1.3705	0.14134
RESIDUES AT HARVEST						
In kernels	BDL		BDL		BDL	
In haulms	BDL		BDL		BDL	

BDL = Below detectable levels

4.6.2. Residues in seedlings

An initial deposit of 0.3661 ppm was recovered from the seedlings which were treated with chlorpyriphos @ 6 ml kg^{-1} seed. The residues decreased to 0.3589 ppm in 5 days, 0.3427 ppm in 10 days and 0.3389 ppm on the 20th day (Table 16).

A similar trend was observed at 12.5 ml and 25 ml kg^{-1} seed treatment. At 12.5 ml kg^{-1} seed treatment the residues of 1.0440 ppm on '0' day reduced to 1.0168 ppm, 0.8966 and 0.7649 ppm on the 5, 1 0 and 20th days respectively.

The initial deposit on '0' day was 1.4077 ppm in 25 ml kg^{-1} treated seedlings. This deposit decreased to 1.3986 ppm, 1.3839 ppm and 1.3705 ppm in 5, 1 0 and 20 days time.

As in the residues in soil, the residues recovered from seedlings were less than 2 ppm which is the maximum residue limit for chlorpyriphos in vegetables. In all the three doses of seed treatment the residues recovered showed a declining trend from 0 to 20 days. When compared to the residues in soil, the residues in the seedlings were always more in all the three treatments (6 ml, 12.5 ml and 25 ml kg^{-1} seed). The residues recovered from seedlings were approximately 10 times more than in the soil in 6 ml and 25 ml kg^{-1} seed, 20 times in the seedlings treated with 12 ml kg^{-1} seed.

4.6.3. Residues in kernels

The kernels sampled at harvest (110 DAS) from the three treatments of 6 ml, 12.5 ml and 25 ml kg^{-1} seed did not record any residues. Even at high doses of 12.5 ml and 25 ml the residues were reduced to zero in the final product i.e. kernels (Table 16).

4.6.4. Residues in haulms

No residues of chlorpyriphos were recovered from the haulms in all the treatments at harvest even at the highest dose of 25 ml kg^{-1} seed (Table 16).

DISCUSSION

CHAPTER V

DISCUSSION

A considerable amount of literature has been built up in recent years on the faunistic study of white grubs in India Over 50 pest species of white grubs have been reported in Indian subcontinent, of which 12 have been found to be key pest species attacking different crops/plants in different regions of the country (Yadava and Sharma, 1995) Of these *Holotrichia consanguinea* Blanch which is the most serious scarab pest dominant in the states of Rajasthan, Gujarat, Haryana, Punjab, U P and Bihar on several kharif crops is especially the main constraint in groundnut cultivation *H serrata* was found to be prevalent in Karnataka, Maharashtra, Andhra Pradesh, Tamil Nadu, Kerala, South Rajasthan, Tarai belt of U P and South Bihar causing extensive damage to vegetables, pulses, oilseeds, cereals, millets, tobacco, sugarcane and sorghum *H reynaudi* has been reported to be one of the major species affecting groundnut all along the central peninsular region in the states of Andhra Pradesh, Karnataka and Tamil Nadu Other predominant *Holotrichia spp* were *H longipennis* Blanch concentrated in the hills of U P causing severe damage to millets, paddy, soybean, potato and chickpea *H seticollis* Moser again is of serious concern in hilly tracts of U P mainly damaging upland rice, *H cortacia* in hilly tracts of Himachal Pradesh and some parts of U P hills particularly damaging seed potato and cedar nursery and *H nilgiria* Arrow is a predominant species serious pest of coffee plantations in Karnataka Among the *Leucopholis* spp the predominant species are

L burmeisteri Blanchard mainly on arecanut and coconut in western coasts of Karnataka,

growing areas is *H. reynaudi* in Andhra Pradesh (Yadava and Sharma, 1995). Though according to Husain (1974), and Pal (1977) *Phyllophaga* or *H. consanguinea* is the major species that is present in the groundnut growing belts of Andhra Pradesh particularly of Anantapur and Kurnool, detailed faunistic study of melolonthid beetles of Karnataka by Veeresh (1977), particularly border districts of Bangalore, Kolar, Tumkur, Chitradurga, Bellari, Raichur, Gulbarga and Bidar of Karnataka surrounding major groundnut growing districts of Anantapur, Kurnool, Chittoor and Mahboobnagar districts of Andhra Pradesh clearly established only the presence of *H reynaudi* or the other species of *Holotrichia*, other than *H consanguinea* There is no evidence of the presence of *H. consanguinea* in the border districts of Karnataka surrounding major groundnut growing districts of Andhra Pradesh and also in entire Karnataka (Veeresh, 1977). Though *H reynaudi* has been reported as a new species, Veeresh (1977) has synonyomised it with *H. insularis* Br. which is a major pest of groundnut in Haryana and Rajasthan (Srivastava and Khan, 1963) and supports the present finding that *H reynaudi* is the major species on groundnut. The current results of the survey from the adult collections followed by laboratory studies on the rearing of grubs into adults, convincingly establishes *H. reynaudi as* the major white grub species associated with the principal groundnut growing areas of Andhra Pradesh. Husain's (1 974) statement of presence of *H consanguinea* as a pest of groundnut in Andhra Pradesh is mainly based on the identification of adult collections but not from the rearings of grubs resulting into adults. But the intensive surveys undertaken during 1995 and 1996 and also the regular surveys that are being conducted by ICRISAT in the groundnut growing belts for the past one decade or even more have not yielded at any time *H. consanguinea* from Andhra Pradesh. There is every possibility that *H. reynaudi* was misidentified as *H. consanguinea* due to there similarities in external morphology and also

L coneophora Burm in the heavy rainfall areas of coastal Karnataka and Kerala *L lepidophora* causes severe damage to sugar cane in Kolhapur region of Maharashtra, and arecanut and coconut in coastal Karnataka Among the 12 root grubs, *Maladera insanibilis* Brenske at Rajasthan on groundnut, chilli, okra, brinjal, alfalfa, onion, cucurbits and *Anomala dimidiata* Hope which is mostly prevalent in Himalayan ranges mainly on upland rice, millets and chilli , are the key pests (Yadava and Sharma, 1995) Such a faunistic study was also made by Veeresh (1977) who reported the distribution of different species of white grubs in Karnataka Similar studies were also made by several other workers (Verma, 1975 and Pal, 1977)

These faunistic studies gave broad indications of distribution of important white grub species in different regions of the country and the crops that are affected The specific crop based distribution of white grub species are lacking at least even to one important crop One of the specific objectives of the present investigation is to study the species of white grubs associated with the important groundnut growing areas of Andhra Pradesh

The collections of grubs made in the present investigation through surveys of important groundnut growing areas of Anantapur, Kurnool, Chittoor of Andhra Pradesh which when reared into adults were identified as only one species, *Holotrichia reynaudi* Recently Yadava and Sharma (1995) probably, based on adult collections, stated that *H reynaudi* is the major species of white grubs affecting groundnut production, all along the central peninsular region of Andhra Pradesh Majority of the adults and root grubs collected through surveys of 1995 and 1996 season from the major groundnut growing areas of Anantapur, Kurnool, Chittoor have been identified as *H reynaudi* (Table 5 and 6) which confirms The previous report that the major species distributed in the groundnut

similarity in adult male genitalia (Khan and Ghai 1982). Recently, Yadava and Sharma (1995) also clearly stated that *H. consanguine*a is the dominant white grub species in the states of Rajasthan, Gujarat, Haryana, Punjab, U.P., and Bihar which is the main constraint in groundnut cultivation in these states. However, further specific surveys preferably in the major groundnut growing areas for adult collections and also rearings of adults from grubs collected can only establish the correct identification of white grubs. It is important to identify the species correctly since the difference in response to lower dose of seed treatment with chlorpyriphos (6.5 ml kg^{-1}) in Andhra Pradesh (Mallikarjun Rao, personal communication) and higher dose (25 ml kg^{-1} seed) in Rajasthan and Gujarat (Yadava and Sharma, 1995) may be due to occurrence of different root grub species in these states.

There are two white grub species which are major pests of groundnut in India. These are *Holotrichia consanguinea* and *H. serrata*. Of these *H consanguinea* is the key white grub pest in the northern parts of the country and finds loose sandy, well drained soil to be quite suitable for its survival and multiplication. It is the dominant white grub species in the states of Rajasthan, Gujarat, Haryana, Punjab, Utter Pradesh and Bihar. *H. serrata* is dominant in Karnataka, Maharashtra, Andhra Pradesh and Tamil Nadu and survives in well drained heavy, red alluvial and black cotton soils (Yadava, 1991). The limited amount of information on their regionwise distribution demands thorough study in this regard and it is likely the type of soil may not be playing any important role in the species distribution. The particular white grub species which is predominant on groundnut at present must have existed in nature feeding on roots of both weeds and crops but due to extensive cultivation and major changes in cropping systems and agricultural practices like ploughing, irrigation etc. in groundnut in these areas the particular white grub species attained the status of serious and endemic status of serious pest of the crop (groundnut). The fact that all the known injurious white grubs in this country have one year life cycle (Veeresh, 1977), adult migration not more than 300 meters after emergence and the larvae confine to the root zone

(Yadava *et al,* 1978) also supports the view of endemic nature of particular root grub species in the specific regions of the country. It has been found that certain white grub species have pest status for a particular cropping system and if groundnut is grown in this endemic pocket, the existing white grub species shall devour the groundnut. For example, *Leucopholis lepidophora* is a serious pest of sugarcane in west coastal region, particularly Kolhapur (Maharashtra) and if groundnut is grown in that region, which is not a common crop, shall be completely destroyed (Yadava, 1991). It is likely that abiotic factors like climatic conditions play important role indicating the prevalence of different root grub species in a particular region on groundnut crop but - this view becomes acceptable only when the studies are initiated in this direction.

The adults have their own preferred hosts whereas at the larvae make no distinction between roots of different plants (Veeresh, 1978). However there is scarcity of attempts to resolve the host preferences of adults. From the observations in the present studies there is an indication that adults do have host preferences for feeding after emergence. *H. reynaudi* was found to show a decided preference to ber than the other hosts like Acacia and drumstick and negligible numbers were found feeding on neem. Similarly *H. serrata* was found feeding voraciously on neem (Table 7) and ber was found to be less preferred. *Schizonycha ruficollis* was mostly found on Acacia followed by ber. The observations of Veeresh, (1977) on the food preferences of *H. serrata* to neem is confirmed by present studies but his observation of *H. reynaudi* feeding preferably on drumstick, and that *S. ruficollis* has a distinct preference to tamarind (Veeresh, 1977) are not confirmed through these studies.

It is most likely that when the preferred host is not available the beetles choose the most available or the nearest available host no matter where it stands in the order of preference. Secondly, if the population of beetles in a locality is large enough to saturate the most preferred hosts, the beetles congregate on less preferred hosts and in such

situations it may be difficult to determine the relative preference of beetles to hosts. It was also observed that even though ber is the most preferred host for *H. consanguinea* it fails to attract the beetles that emerge very early after premonsoon showers because at this time of the year ber bear small number of old leaves, the new flush appears only by the end of May in Rajasthan. In such situation Khijri (*Prosopis cinereria*) and Gular (*Ficus glomerata*) may appear to be the most preferred though it is less preferred by this species under normal conditions (Yadava *et al,* 1978). They further stated that beetles could feed on a large number of different kinds of host trees. Such observations were also made by Rai *et al* (1969) and Bindra and Singh (1971). In many situations, beetles immediately after emergence from soil settle in large numbers on some non- host trees simply for mating and later on shift to their hosts. Such trees are often confused as hosts.

The available information on the host preferences of adults is primarily based on the casual observations during adult collections but not on the choice tests. Any future attempts to determine food preferences of the adult beetles with choice and no-choice tests will help in mass trapping through collections and spraying of specific host trees for the control of adults in the endemic areas. Large scale collections of *Leucopholis lepidophora* in Kolhapur area of Maharashtra and spraying of neem and ber for reducing the incidence of grubs by controlling the adults of *L. lepidophora* by insecticidal application to host trees are some of the successful attempts (Yadava and Sharma, 1995).

The present survey revealed that *Holotrichia reynaudi* is the major species of white grub abundant in the groundnut growing tracts of Andhra Pradesh. So far the information is lacking regarding its life-cycle, except the studies of Srivastava and Khan (1963) who have worked on the bionomics of *H. insularis* and this species was synonymised with *H. reynaudi* by Veeresh (1977). Emergence of the beetles during monsoon rains, copulation

time during dusk (for 15 minutes), preoviposition period the, site of egg-laying, egg size and transformation of eggs from pearly white (when laid) to turning globular and dirty white before hatching, are similar to *H. insularis.* Similarly the head capsule and other morphometrical observations of the grub (Table 8) of three instars, pupation in the earthen cell and duration of the pupal period conform with those reported by Srivastava and Khan (1963). for *H. insularis.* Eclosion of adults have been observed in October-November in the laboratory and such an off-season emergence in October was also seen under field conditions which needs to be studied further. The similarity of life cycle.of *H. reynaudi* with that of *H. insularis* (Srivastava and Khan 1963) broadly confirms the synonomy proposed by Veeresh (1977). However, a detailed study of the bionomics of *H. reynaudi* is necessary to find out weak links in the biology which may be exploited to evolve management strategies .

The control of white grubs by chemicals has been tried by several workers in India (Kalra and Kulshreshta, 1961; Srivastava and Khan, 1963 ; Desai and Patel, 1965, 1966; David and Kalra, 1966; Patel *et al,* 1967; Joshi *et al,* 1969; Rai *et al.,* 1969; Sharma, 1969;, Sharma and Shinde, 1970; Bindra and Singh, 1971; Veeresh, 1973; Bindra *et al.,* 1973; Yadava and Yadava, 1973; Sachan and Pal, 1974, 1976). Dwivedi *et al,* (1976) reviewed the work on the evaluation of insecticides against white grubs conducted in the country and opined that soil application of phorate granules was superior to other insecticides. Other insecticides like carbofuran granules were also promising in the reduction of grub populations (Srivastava *et al,* 1981). However, high dose and cost of the granules are prohibitive for the farmers to take up control measures against root grubs. To overcome this problem an equally effective treatment has been evolved with

chlorpyriphos 20 EC at 25 ml kg^{-1} as groundnut seed treatment (Srivastava *et al*, 1982) and now it is a national recommendation against the root grubs in groundnut (Yadava and Sharma, 1995). Interestingly several extension demonstration trials conducted with chlorpyriphos seed treatment at 25, 12.5 and 6.25 ml kg^{-1} seed in the root grub endemic areas of Ananthapur district, Andhra Pradesh have conclusively proved that the lowest dosage of 6.25 ml kg^{-1} seed was nearly as effective as the high doses (Mallikarjuna Rao, personal communication). The present investigations also clearly demonstrated that chlorpyriphos seed treatment at 6.0 ml and 12.5 ml kg^{-1} gave grub mortality of 85 and 90 per cent respectively with negligible difference between the doses (Table 9). It is evident from the data that 6.0 ml kg^{-1} seed is enough to control the grubs of *H. serrata* effectively. Investigation on the response (control) of *H. reynaudi* grubs in major groundnut growing tracts of Andhra Pradesh to lower dose (6ml kg^{-1} of seed) of chlorpyriphos compared to 4 times the dose. (25 ml kg^{-1} seed) required by the grubs of *H. consanguinea* in Rajasthan and Gujarat, will only clarify whether the differential response is due to the difference in root grub species.

It is evident from the data that in plots planted with chlorpyriphos treated seed there was higher percent larval mortality and larval weight gain was positive (though it was far less compared to control with regard to plant mortality) (Table 9). The above observations indicate a that the grub mortality may be due to contact action of the chemical present in the soil or due to chemical translocated into the seedlings acting on the grubs when it is ingested during feeding on the roots. The positive weight gain clearly indicates that the grubs might have fed on the roots of chlorpyriphos treated groundnut plants and ingested the chemical along with the food.

Although chlorpyriphos is generally treated as a non systemic insecticide with contact and stomach action (Tomlin, 1994), it is absorbed by roots and leaves and there is some translocation (Hartley and Kidd, 1983). The residues of chlorpyriphos were observed in the groundnut seedlings even upto 20 days after treatment (Table 16). The higher percentage of grub mortality in chlorpyriphos treated plots might be due to contact action of insecticide as the residues were recorded form the soil 10 days after treatment and also due to residues available in the seedlings 20 days after treatment (Table 16). The amount of residues recorded in the soil in all the three doses of chemical tested was less than that in the seedlings (Table 16). It has been a common topic of discussion in various forums as to how chlorpyriphos as a seed dressing chemical, brings about the kill of root grub. For the first time it is proved without doubt, the mode of action of chlorpyriphos as a seed dressing chemical based on residues present in soil and seedlings. The adult beetles emerge soon after monsoon showers in the later parts of June and lay eggs in the fields before sowing of groundnut is done. The first instar grub hatches in 7-13 days and starts feeding on organic matter (Veeresh 1978 and Yadava 1991). Later when groundnut is sown in early July, the later instars start feeding on the groundnut seedling. This goes to show that the Ist instars are killed probably by contact action, the later instars may die due to feeding on the roots of seedlings as it is evident that residues recovered from seedling were more than those in the soil . Though the present study recorded residues upto 20 days after treatment only, Logan *et al* (1992) showed that chlorpyriphos residues were detectable in the soil even upto 92 days. Paddy seedlings treated with chlorpyriphos 20 EC @ 0.02% as seedling root dip recorded residues of 0.2661 mg/kg at 30 days after transplanting showing that chlorpyriphos is translocated into the seedling (AICRP on pesticide residues, 1995b) These

instances further confirm the effectiveness of chlorpyriphos as seed treatment as against the root grubs. This view becomes even more acceptable when it is demonstrated with further studies that residues available in such low quantities in soil (0.0170 to 0.339 ppm) and seedlings (0.3389 to 0.3661 ppm) are lethal to the grubs. The positive weight gain of the grubs feeding on the groundnut seedlings in chlorpyriphos treated plots may indicate that the antifeedant action of the chemical may be nil or negligible. However, further studies are needed to confirm this hypothesis.

There is no published FAO/WHO recommended maximum residue level (MRL) for chlorpyriphos in groundnuts. MRL's of upto 2 mg kg^{-1} are suggested for various vegetables but the most relevant is probably that for cotton seed oil i.e. 0.05 mg/kg (FAO/ WHO 1986). Residues of chlorpyriphos below detectable levels at harvest in the kernels and haulms clearly indicate that seed treatment with chlorpyriphos is safe without any toxic hazards.

Imidacloprid, a chloronicotinyl insecticide, available as a water dispersible powder used as a seed dressing chemical like chlorpyriphos was also very effective against root grub in groundnut. It has been tried out against *H. serrata* grubs for the first time. Imidacloprid at a higher dose (10 g kg^{-1} seed) was on par with chlorpyriphos in controlling the grub. The recommended dose of 5 g kg^{-1} seed of imidacloprid also gave grub mortality to an extent of 66% (Table 9) which is however less when compared to recommended dose of chlorpyriphos (6ml kg^{-1} seed).

Though the grub mortality was less in the imidacloprid treated plots, it restricted the feeding of the grubs, which is evident from the negative mean larval weight gain recorded in these plots (Tables 9 - 13). Antifeedant action was present persistently till 40 DAS (Table 10, 11, 12) in the imidacloprid treated plots, where as it was not consistent in the chlorpyriphos treated plots. This indicates that the active ingredient in imidacloprid treated plots shows excellent root systemic properties and that is translocated acropetally and shows antifeedant action. Similar results were presented with regard to lower larval mass gain due to restricted feeding in *Somaticus* spp. (False wireworms) which feed primarily on subterranean stems of maize seedlings. (Drinkwater, 1994). The negligible plant mortality when commpared to chlorpyriphos treated plots coupled with negative larval weight gain and lower mortality conclusively establish the antifeedant action of imidacloprid. Imidacloprid as a seed treatment chemical was found to be very effective against aphids and soil pestts in sugar beet (Dewar and Read, 1990; Schmeer, 1990; Mittnacht, 1994; Bosch and Schaufele, 1994). In France, Belgium and Spain, the sugar beet seeds are pelletted with imidacloprid which protects the crop against the early season pests like the marigold beetle *Atomari linearis* and wire worm, *Agriotes* spp. At very low concentrations it showed antifeeding effect in termites leading to death (Leicht, 1993).

Seed treatment is an age old technology, Its history, development application techniques and a review of pesticides used on different crop seeds comprises a modern monograph (Jeffs, 1986). More recent progress in technology of seed treatment was the subject of a symposium (Marten, 1988) and later a synthesis of the scientific advantages and disadvantages of these developments was made by Suett (1988). In groundnut chlorpyriphos has been applied as a seed dressing chemical since 1982 when it was found

effective against root grubs (Srivastava *et al*, 1982). Persistence of chlorpyriphos was less in cultivated soil in the tropics, giving only limited control (Wood *et al*, 1987). To increase the active life the less persistent insecticides can be incorporated into an inert matrix from which they are slowly released. But such control release formulation with plastic pellets are not cost effective in the semi arid tropics (Logan *et al*, 1992). Therefore seed pelleting with locally available inert and adhesives was attempted for the first time to increase the persistence of chlorpyriphos. Groundnut seed pellets consisting of gum arabic, chlorpyriphos and gypsum offered several advantages over conventional seed dressing. They are (a) no damage to testa, (b) no direct contact with insecticide, (c) seed pellets registered significantly higher pod yield (160 g 0.7 m^2) than chlorpyriphos applied singly as seed dressing chemical (119 g 0.7 m^2) (Table 13). The higher yield can be explained by the fact that gypsum is known to enhance the yield of groundnut (Sagare *et al*, 1986). Bhaskar and Sivashankar (1993) tested gypsum and "S" pelleted seed on the productivity of groundnut. Gypsum pelleting @ 12 g kg^{-1} seed + 250 kg of gypsum ha^{-1} at flowering gave the highest net return with highest pod yield. However, further trials in the field are essential to see its performance when used on a large scale.

Hence seed treatment as a seed dressing or a seed pellet increases the effectiveness of the reduced dosage of insecticide due to availability of concentrated amount of insecticide through seed in soil around root zone which makes it toxic enough to kill the younger grubs (Kumawat and Yadava, 1990).

White grubs sever fine roots, often close to the taproot of the groundnut, the result being elimination of relatively large amount of water-absorbing area even when only a small amount of tissue is eaten. As the attacks come mainly during the late seedling stage,

they can affect the growth or even kill the plant, particularly if soil moisture is limited. There are many generalisations in the literature about the degree of damage caused by white grubs to groundnut crops, but few give specific data or attempt to relate insect number to damage (Wightman *et al,* 1990). It should be noted that in the present investigations plant mortality even in the untreated control was very low ranging 4.7-15.7% (Tables 9-12) when 10 to 20 grubs were released per microplot of 0.7 m^2. As per the information available, in groundnut, the presence of one grub m^2 may be enough to cause mortality of 80 - 100 per cent plants and the population of 10 to 20 grubs 0.7 m^2 must be enough to cause 100% mortality. Because of the tap root system and smaller amount of roots, the damage to groundnut is more pronounced as compared to fibrous rooted crops like pearl millet, sugarcane and sorghum (Yadava and Sharma 1995). Further experiments preferably under more controlled conditions will only be able to clear the doubt why such low plant mortality was observed in the present investigations. The highest percentage of 30.7 plant mortality observed at harvest in the untreated control plots (Table 13) cannot be attributed to white grubs alone and it is likely that other soil organisms (especially termites) may also be involved (Wightman, 1989).

For managing the populations of white grubs efforts are to be directed against both the stages *viz.*, beetles and the grubs. Most of the scarab beetles which attack kharif crops emerge from the soil with first soaking shower of premonsoon or monsoon and congregate on some preferred hosts and can be killed conveniently by spraying of insecticides (carbaryl 0.2% or monocrotophos or chlorpyriphos 0.05%) during evenings just after the onset of monsoon. In the present investigations the predominant species in the groundnut growing tracts of Andhra Pradesh *H. reynaudi* showed a preference to ber followed by Acacia, whereas *H. serrata* preferred neem but not ber. Hence ber and Acacia have to be sprayed invariably for the control of adult beetles in the groundnut growing tracts of Andhra Pradesh. Generally it is argued that the beetle control will be effective only with the

community approach by spraying entire village or region but as the beetles do not fly long distances individual efforts by the farmers shall also provide protection to the crop in his fields (Yadava and Sharma, 1995). However, community efforts will give better results in the case of adult control.

In the event of lack of motivation or desire on the part of the farmers to adopt beetle control, the only suitable alternative is grub control. Presowing soil treatment with phorate 10 G at 25 kg ha^{-1} effectively protects the crop but it is not economical (Rs.2280 ha^{-1}). Since the seed treatment in groundnut with chlorpyriphos 20 EC at 6 ml kg^{-1} seed is quite effective and very economical (Rs. 227 ha^{-1}), with no residues in kernel or haulms, it is recommended for adoption. The seed pelleting developed for the first time in groundnut also facilitates easy application with negligible additional cost (Rs.20 ha^{-1}) which is compensated by increased yield due to use of gypsum as an ingredient in seed pelleting. The present investigations also demonstrated that imidacloprid can also be used as a seed dressing chemical in groundnut for the protection against root grubs, provided the chemical is registered in our country and also economical in terms of cost compared to chlorpyriphos. In addition it also reduced the incidence of groundnut leaf miner and thus resulting in significantly higher pod yields.

From the present investigations on the applied ecology of root grubs in the groundnut ecosystem the following broad conclusions have been drawn.

The faunistic study of melolonthid and rutelinid beetles occurring in the principal groundnut growing tracts of Andhra Pradesh revealed that *H. reynaudi* is the most abundant

species associated with groundnut. *H. serrata* was another species of white grub collected in large populations of beetles from ICRISAT. Distinct host preferences have been observed by the adult beetles. *H. reynaudi,* was found feeding on ber and *H. serrata* on neem.

The life cycle of *H. reynaudi* was studied in detail and is similar to *H. insularis,* a synonym of *H. reynaudi.*

Seed dressing chemical chlorpyriphos was found effective at lower dose of 6.0 ml kg^{-1} seed on grubs of *H.serrata.* The mode of action against grubs appears to be contact and also due ingestion of the chemical translocated into the groundnut seedlings. The residues were found to be below detectable levels in the kernels and haulms at harvest indicating the safety of seed treatment. Seed pelleting was developed with gum arabic, gypsum and chlorpyriphos for the first time, which facilitates uniform distribution of the chemical without any damage to testa. Imidacloprid, a nitromethylene insecticide found to be more effective than chlorpyriphos, is systemically translocated to seedlings and has antifeedant action inhibiting larval feeding. Being systemic in nature this chloronicotinyl insecticide was found effective against leaf miner also which is again a major pest of groundnut.

SUMMARY

CHAPTER VI

SUMMARY

Investigations were carried out on the applied ecology of white grubs associated with groundnut in Andhra Pradesh to identify the dominant species involved, its biology and the management strategies by seed treatment. Surveys for the collection of grubs and adults from the root grub endemic areas of major groundnut growing tracts of Andhra Pradesh viz., Anantapur, Kurnool, Chittoor and Mahboobnagar districts were undertaken in the rainy seasons of 1995 and 1996. The laboratory and field studies throughout the investigation were carried out at ICRISAT Asia Center, Patancheru, Andhra Pradesh.

The surveys yielded 5 genera of melolonthinae and 3 genera of rutelinae associated with groundnut. *Holotrichia reynaudi*, *H. serrata*, *H. rufoflava*, *Schizonycha ruficollis*, *S.* decipiens and *S.fuscescens* were the important melolonthids identified based on the male genitalia and adult characters. The grubs collected from groundnut fields in Anantapur, Kurnool, chittoor and Mahboobnagar that were reared to adults were identified as a single species i.e. *H. reynaudi.* Rutelinids like *Adoretes* spp, *Anomala* spp were mostly collected from light traps at ICRISAT.

Adults of *H.reynaudi* were found feeding in large numbers on ber and to a lesser extent on Acacia. Neem was not found to be a preferred host. On the contrary *H. serrata* showed a definite preference for neem.

The life history of *H. reynaudi* the principal white grub species associated with groundnut was found to be similar to *H. insularis*. Emergence of beetles during monsoon rains, copulation during dusk, preoviposition period, egg size, site of egg laying transformation of egg, morphometrical studies of the grub, larval and pupal durations, pupation in earthen cell was similar to *H. insularis*. Occasionally off season emergence of adults was observed in October/November.

Investigations taken up in the micro plots at ICRISAT Asia center on the chemical control of white grub through seed treatment with chlorpyriphos 20EC @ 6ml and 12.5 ml kg^{-1} seed and a new insecticide imidacloprid 70WS @ 5g and 10g kg^{-1} seed yielded good results. Both doses of chlorpyriphos were effective against the grubs of *H. serrata*. Imidacloprid at 10g kg^{-1} seed was on par with chlorpyriphos in its efficacy. The lower dose of 5g kg^{-1} seed though caused only 66% larval mortality, registered a negative larval weight gain indicating antifeedant action.

Groundnut seed was pelleted with gum arabic (100 ml of 27% gum arabic /kg seed) as a sticker, chlorpyriphos (6 ml kg^{-1} seed) and gypsum (120 g kg^{-1}) as a binding material. The shade dried pelleted seeds can be used for sowing after 12 hrs and this technique was found to be useful in preventing damage to testa of kernels during application of chlorpyriphos as a seed dresser.

Groundnut seed pellets developed with chlorpyriphos (6 ml kg^{-1}) gave highest mortality of grubs at 20, 30 and 40 days after sowing followed by chlorpyriphos and imidacloprid applied as seed dressing chemicals. Imidacloprid was also found to be promising as it recorded zero plant mortality and negative larval weight gain which reflected in the recovery of highest pod yield as it had an antifeedant effect on the grubs. Plant mortality and larval weight gain was also less in chlorpyriphos seed pelleting when compared to its application as a seed dressing chemical.

Seed pelleting did not affect the germination of groundnut. The additional cost incurred was also marginal over chlorpyriphos used as a seed dresser.

Residues of chlorpyriphos applied as seed dressing @ 6, 12.5 and 25ml kg^{-1} seed were estimated in soil and seedlings at 0,5 10 and 20 days after treatment and in kernels and haulms at harvest by GC. In the soil the residues ranged from 0.0339 ppm at '0' day to 0.0170 ppm on 20th day at a dosage of 6ml kg^{-1} seed. In 12.5 ml and 25 ml doses the residues increased from '0' day to 5th day and progressively decreased. The residues recovered from the seedlings in all three doses were higher than those in the soil. The residues in the seedlings were also well above he MRL of 0.05 mg kg^{-1}. The residues gradually decreased from 0.3661 ppm to 0.3389 ppm on the 20th day in 6 ml, 1.0440 to 0.7649 ppm in 12.5 ml and 1.4079 to 1.3705 ppm in 25 ml kg^{-1} seed treatment. However the residues were below detectable levels in kernels and haulms at harvest in all the three doses of chlorpyriphos applied as a seed dressing.

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