# Insect and Other Animal Pests of Millets



**Sorghum and Millets Information Center**
INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

# Insect and Other Animal Pests of Millets

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## FOREWORD

Pearl millet is a staple cereal best suited to the harsh climate of the seasonally hot, frequently drought prone semi-arid regions of Africa and the Indian subcontinent. It is grown on an estimated 26m ha in these two regions and constitutes the major staple crop in the Sahelian region of West Africa.

Considerable advances have been made in grain yields on other crops such as rice, wheat and corn - crops that are extensively cultivated in areas with favorable soil and climatic conditions and high technological inputs. Pearl millet and sorghum are usually cultivated in poor soils with little or no inputs by poor farmers. However, pearl millet is highly adaptable, providing sustainable yields under extreme environmental and biotic stress conditions. This crop has the potential to feed several millions of the poorest people of the semi-arid tropics and thus reduce the economic imbalance in those countries that are today highly dependent on food imports.

The importance which ICRISAT attaches to this crop is evidednced by the establishment of the regional ICRISAT Sahelian Center at Sadore, near Niamey, NIGER. Among the major constraints to millet production, insect pests diseases, birds and rodents cause severe yield losses to a crop that provides considerable calories and protein in human diets.

By providing a comprehensive overview of the major pests of pearl millet, this book will meet the requirements of several scientists, technicians and extension agents actively involved in the improvement of this crop especially in countries where it is the major staple crop.

February 1988

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## ACKNOWLEDGEMENTS

We are grateful to Dr. K. Leuschner, Dr. W. Reed, Dr. A.B.S. King and Dr. D. Dent for going through the manuscript and making some valuable suggestions. The help received from the Sorghum and Millets Information Center is gratefully acknowledged. We are also grateful to Mr. D.J. Andrews and Dr. S.B. King for their interest and encouragement in the preparation of this state of the art review on pest problems in millets.

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# 1. INTRODUCTION

Millets are one of the most important cereal crops in the semi-arid tropics of the world, and form the staple diet of millions of people in Asia and Africa. Rachie and Majmudar (1980) reported that the average world production of millets for the five year period 1967-1971 was nearly 44 million metric tons produced on 68.8 million hectares. This accounted for 10.6% of the worlds' cultivated land and about 4% of the total grain production. Among the different millet species, pearl millet (Pennisetum americanum Leeke) occupies 46% of this area and accounts for nearly 40% of the total millet production. Foxtail millet (Setaria italica Beauv.) (grown mostly in China and Manchuria) comprise about 24.2% of total millets produced. Proso millet (Panicum miliaceum Linn.) occupies 14% area and 15% of the production (mainly in China and USSR). Finger millet (Eleusine coracana Geartn.) accounts for 8 and 11% of the area and production respectively. Fonio (Digitaria spp) and teff (Eragrostis teff Trott.) are grown on a small scale in West Africa and Ethiopia respectively. A number of other minor millets and their wild relatives are also grown on a small scale or occur under wild conditions in different parts of the world, and may be used either as human food or animal fodder. The different species of millets and their closely related wild species reported as potential hosts of insect pests are listed in Table 1.

Pearl millet is most important in the developing countries of the semi-arid tropics of Asia and Africa where annually an estimated 28 million ha is planted to this crop. It also occupies an important place as fodder for animals, both in the developing and the developed world, (e.g. it is grown as a forage crop on about 40,0000 hectares on the coastal plains of USA). The crop is grown in areas with an annual rainfall of 300-800 mm where the soils have poor fertility or are sandy and is usually raised on small farms, with a very low level of inputs in the form of fertilizers, labour, cultural operations, and management. It is commonly regarded as a poor mans' crop.

In India, the crop is grown in Rajasthan, Gujarat, Tamil Nadu, Haryana, Madhya Pradesh, Maharashtra, Uttar Pradesh, Punjab, Andhra Pradesh and Karnataka. Rajasthan, having light sandy soils and low rainfall, is the principal millet growing state and accounts for over 40 percent of the total acreage under millets. In India, the crop comes fourth after rice, wheat, and sorghum and covers 10.7 million ha. In Africa the major areas of pearl millet production lie between 10 N to 17 N, while in Asia, more than 80% of the pearl millet is produced north of the 18 N parallel.

Efforts to improve upon this crop were initiated in the early sixties in India. One of the major constraints to increase crop yields is the susceptibility of high yielding genotypes to diseases such as ergot and downy mildew, which only became important after the first phase of the crop improvement program.

The average national grain yield is about 560 kg/ha in India and 600 kg ha in the African countries with a low of 275 kg/ha in Mauritiana (FAO 1978). Grain yields of 2.0 to 3.5 metric tonnes/ha can be obtained on research farms, and there is a yield gap of 4-10 times between what can be produced under optimal conditions with presently available potential genotypes, and that produced on farmers' fields in the semi-arid tropics. Factors such as drought, low soil fertility, suboptimal management, diseases, parasitic weeds, birds and insect pests reduce the crop yields substantially. There is considerable malnutrition and undernutrition in most of the countries in the semi-arid tropics (SAT), which necessitates a doubling of the agricultural production in these areas over the next 1-2 decades. However, the available resources such as irrigation and agrochemical inputs are unlikely to change substantially. These constraints must be overcome by developing cultivars with greater ability to tolerate abiotic and biotic yield reducing factors, and by improving crop husbandry practices.

Millets are reputed to be relatively free of insect pests when compared with other cereals such as sorghum, rice, and maize. However, this is not true in many areas in Africa, where the millets are attacked by a wide range of pests which may damage the crop at all stages of development. Although the need to control pests on millets is less frequent than on other crops, the production may be significantly reduced in certain areas.

Insect pest problems on pearl millet are generally considered to be more important in Africa than in India where the crop is often said to have no serious pest problems. While insect pests of millets have seldom reached epidemic proportions, serious outbreaks and locally important endemic pests have been reported from time-to-time. In India, the outbreaks of Holotrichia fissa (Verma 1975), Schistocerca gregaria (Maxwell-Darling 1936; Haroon Khan 1945), Oedaleus senegalensis (Bhatia and Ahluwalia 1966), and Balclutha sp. (Khurana and Ramakrishnan 1974) have been reported. In Africa Oedaleus senegalensis (Mallamaire 1948) and Raghuva albipunctella (Vercambre 1978; Ndoye 1979) have been recorded in outbreak proportions. Pearl millet diseases were considered to be unimportant before 1970. But these now cause colossal losses year after year. Taking a clue from the sister crops such as sorghum, where insects of minor importance have become major and key pests, it is high time to take a critical look at the insect pest problems on millets.

Whereas there is little specific information on the insect pests of millets in the literature, a number of preliminary reports list the various insect species found feeding upon millets. In some cases, information on the life histories and behaviour of these insects and their control is also included. Pest problems in pearl millet have been discussed by Kassam (1976), Jotwani (1976; 1978), Jotwani and Butani (1978), Rachie and Majmudar (1980), Gahukar and Jotwani (1980), Gahukar (1984), Verma (1980), and Ndoye et al. (1986). However, there is no comprehensive account of the pest problems on millets in Asia, Africa and America.

Many insect and mite species also attack the stored grain, which cause both quantitative and qualitative losses. Fourteen species have been reported to attack stored millet grain, however, it is most likely that the insects damaging other cereals and their processed products damage the millets as well. The exact yield loss estimates are not available, though, the storage losses can be very high.

Grain eating birds, by far are the most important pests of millets, and the losses are very high in the sub-Sahelian Africa. A large number of species feed on the grain in the field.

Rats and mice also damage millets substantially, both in the field and in the stores. Serious outbreaks are often observed periodically, that result in heavy damage.

## 2. INSECT AND MITE PESTS

The insect and mite pests reported feeding on millets in different parts of the world are listed in Table 2. The pest problems of millets are generally underestimated. However, a careful appraisal of the literature shows that there are many important pests but not much attention had been paid to pest problems on millets until recently.

There is very little information on the nature of damage, biology, seasonal activity, incidence, and extent of losses due to insect pests feeding on millets. Most of the reported work deals with the occurrence, nature of damage and unusual outbreaks.

### 2.1. ECONOMIC IMPORTANCE

Information on pest incidence and associated crop losses is scanty and reported in case of a few insect pests only. This information is summarized in table 3. The number of pests damaging millets and their role will become more clear in future when necessary emphasis is placed on insect pest management in millet production, and incidence levels and subsequent yield losses encountered are worked out in different parts of the semi-arid tropics (SAT). From the preliminary reports it is evident that insects such as shoot flies, stem borers, and earhead caterpillars may account for more than 50 percent of the crop yield loss (Table 3). Based on the information on pest outbreaks, their geographical distribution, the plant parts attacked and the potential to cause damage, a number of highly injurious insect pests can be singled out. With the change in cultivated genotypes (land races being replaced by new cultivars), cultural practices, and farming systems, these insect pests might become a limiting factor in millet production in future.

### 2.2 NATURE OF DAMAGE, BIOLOGY, AND SEASONAL ACTIVITY

Most of the work reported on insects feeding on pearl millet contains very little or no information on the nature of damage, biology or seasonal activity. Adequate knowledge of the insect biology and population dynamics is of prime importance to the development of successful pest management strategies. In this section, the available information on the biology, pest status, and nature of damage of important pests has been summarized.

#### 2.2.1.ROOT FEEDERS

##### 2.2.1.1. White Grubs

The white grubs, Holotrichia spp are the most important pests of pearl millet in North-West India. The grubs feed on roots and live inside the soil at a depth of 2 to 25 cm (Plates 1 and 2). There may be two to three grubs attacking a single plant. The damage leads to the withering and death of seedlings, and such seedlings can be easily pulled out. The mature plants remain stunted in growth and become pale yellow in color and are prone to lodging. The biology of H. consanguinea and H. (insularis) reynaudi, the most destructive species, has been studied by Krishnaswamy et al. (1963), Srivastava and Khan (1963), Bindra and Singh (1971), and Srivastava et al. (1971b); and that of H. serrata by Majumdar and Teotia (1965). The females lay eggs about 10 cm deep in the soil. The eggs hatch in 1-3 weeks. A large number of grubs are present in the soil in June. The grubs feed on roots and other available organic matter and complete their development within 8-22 weeks. The last instar larvae are most damaging. During September, the grubs descend to greater depths for pupation. The pupal period lasts for 1-6 weeks. The insect completes one generation per year and the peak period of attack is from August to September.

The adults may emerge by November-December if the climatic conditions are favourable, but generally remain in the soil until the monsoons and emerge mostly during June-July and defoliate the preferred host trees and shrubs. The activity declines with heavy showers of rain. At dusk, the beetles make nuptial flights and feed on the leaves of trees and shrubs. At dawn, they hide in the soil (Jotwani and Butani 1978). Adults of H. consanguinea and H. reynaudi are attracted to light (Khan and Ghai 1974).

2.2.1.2 False Wireworms

The false wireworm, Arthrodes sp larvae live in the soil and feed upon the roots, leading to withering of plants (David and Kumaraswami 1975). The larval damage increases with crop age and roots may be completely eaten away by the time the plant reaches the earhead stage. The plants dry up and produce chaffy heads. Damaged plants are pulled up very easily. A severe infestation may result in loss of the entire crop (Rangarajan 1965). The larvae remain at a depth of 2-30 cm, and 2-3 larvae may be found below one plant. Peak activity occurs between December-January in South India. The larvae are unable to withstand excess moisture in the soil, with the result that crops are less severely damaged in years of high rainfall. The round black adult beetles appear in large numbers during September-October. Gonocephalum spp are also important pests of pearl millet and sorghum (Sharma and Davies 1982). The larvae damage the seedlings (Plate 3) which fail to establish and later they damage the roots. The damaged plants can be easily pulled out. The adults (Plate 4) feed on the leaves of sorghum, pearl millet and pigeonpea.

2.2.1.3.Root Bug

The root bug, Stibaropus minor occurs on pearl millet in the states of Maharashtra, Rajasthan, and Uttar Pradesh (Srivastava and Siddiqui 1967; Kadam and Patel 1960). The pest thrives in extremely sandy soils. A large number of insects suck sap from the rootlets below ground level and as a result, the plant loses its vitality, the roots begin to decay and the plant dies (Jotwani and Butani 1978). The soil surface at the base of infested plants shows a number of holes made by the adults. Severe infestation may necessitate resowing (Nair 1975). Peak activity occurs during August and then declines gradually

(Srivastava and Siddiqui 1967).

2.2.1.4. Finger Millet Root Aphid

Finger millet root aphid, Tetraneura (hirsuta) nigriabdominalis is found in colonies on the roots, and is usually accompanied by ants at the collar zone. Commonly known as the white plant louse, this pest infests the roots of finger millet in South India. Infested plants become yellow, stunted and produce shrivelled grains. This pest also infests rice (Nair 1975; Chandrsekaran et al. 1975).

2.2.2.SEEDLING PESTS

2.2.2.1. Shoot fly

The pearl millet shoot fly, Atherigona approximata has been reported to be a serious pest in Tamil Nadu (Natarajan et al. 1973), Gujarat (Gupta and Pareek 1976), Rajasthan (Sharma and Bhagirath Singh 1974), Delhi (Jotwani and Singh 1971), and Andhra Pradesh (Reddy and Davies 1977). Although, other species of the genus Atherigona have been reared on pearl millet (Reddy and Davies 1977), A. approximata has been found to be the most destructive (Singh and Jotwani 1973).Regupathy and Balasubramanian (1978) reported that yield reduction may be significant when infestation occurs within the first 21 days after crop emergence. The eggs are laid singly on the under surface of the leaves. Upon hatching, the larvae move to the growing point and cut the central leaf, resulting in the production of a dead heart. In many instances, the larvae are not able to reach the growing point, and as a result, the dead heart is thrown off and the growing point develops normally (Plate 5). Sometimes the larvae feed on the tender leaf blades in the short and the damaged margins become deep brown in color. The biology of this insect has been studied by Ballard and Rao (1924). The egg, larval and pupal periods last for 1-2, 7-9, and 6 days respectively. Unlike sorghum shoot fly, maggots of this fly also damage the earheads severely (Plate 6). A number of other shoot fly species have been recorded on various millets. Their relative importance as yield reducing factors is largely unknown.

2.2.2.2. Stem Borers

Twenty two species of Noctuids and Pyralids have been reported feeding inside the stems of pearl millet and other minor millets. Information concerning the pest status of these insects is not yet available. The stem borers are of considerable importance both in India and Africa (Harris 1962; Sandhu et al. 1976). Chilo partellus and Sesamia spp are the most important species in Asia and Africa, whereas Acigona ignefusalis is the major species in West Africa. Sesamia spp are more serious on late maturing cultivars in high rainfall regions, whereas A. ignefusalis is predominant in relatively dry areas in West Africa (Ndoye et al. 1986).

Acigona ignefusalis is the most important millet stem borer in Africa. Notes on the biology of this insect have been published by Risbec (1946, 1950), Appert (1957), and Harris (1962). The adults have golden brown forewings, and emerge between 19.00 to 23.30 h. Normally, there are more females than males. The oviposition period lasts for 1-6 days and eggs are laid between the leaf sheath and stem in batches of 2-50. A female can lay up to 211 eggs. The eggs hatch in 8-11 days. In contrast to the larvae of Busseola fusca, the larvae of A. ignefusalis rarely leave the protection of the leaf sheath. Small plants may become thoroughly riddled by larvae, with the subsequent collapse of the plant (Plate 7). Larval survival is higher in this species than in B. fusca because the larvae do not leave the leaf sheath. There are 6-7 instars and development is completed in 30-40 days during the wet season. With the onset of dry season larvae enter diapause which lasts for 6 months but may continue for up to one year. Larvae in diapause can be distinguished by the loss of dark pigments and becoming an uniform pale-yellow to creamy white in color (Plate 8). The larvae pupate inside the stems (Plate 9). Pupal period lasts for 7-13 days. There are three generations per year (Harris 1962).

Chilo partellus is a predominent stem borer species damaging millets in India. It is distributed both in Africa (Nye 1960; Ingram 1958), and India (Issac 1946; Ahmed and Young 1969; Sandhu et al. 1976). Larval feeding leads first to leaf scarification and then to shot holes, followed by dead heart formation (Plate 10). The larvae riddle the stem from the inside (Plate 11) and there may be up to 20 larvae in one plant. The stems of attacked plants break easily. While accounts of its biology are not available from Africa, the following is based on the studies carried out in India (Nair 1975). The adults of C. partellus are nocturnal in habit. The pre-oviposition period lasts for 1-3 days and adults survive for 2-12 days. The eggs are flat and oval, and laid in overlapping clusters on the undersides of leaves near the midrib. A female lays on an average 225 eggs and a maximum of 722 eggs. The egg incubation period lasts for 2-5 days. The full grown larvae are light pink in color with dark spines all over the body and with a brown-black head (Plate 12). Larval development is completed in 28-50 days in summer and in about 190 days during the winter. The larvae hibernate during winter and aestivate during summer in stems and stubbles. The larvae pupate in the stem. The pupal period lasts for 12-15 days. The adults are light brown-grey in color and have characteristically long palpi projecting in front of the head when the moth is at rest (Plate 13).

Eldana saccharina occurs throughout Africa. The young larvae feed on leaves and usually bore into the midrib. Full grown larvae feed on stem and produce a deadheart. A female lays 400-600 eggs in batches of 2-200. Eggs hatch in 5-7 days and larvae complete development in 20-60 days. Pupation occurs inside the stem and adults emerge in 8-13 days.

Sesamia calamistis is widely distributed in Africa. Early instar larvae feed inside leaf sheaths, while the later instar larvae tunnel inside the stem through the internodes. Eggs are laid between the leaf sheaths and the stalk in groups of up to 400 Eggs hatch in 4-6 days and the larval development is completed in 2 weeks. Pupation takes place inside the stem and lasts for nearly 10 days. Unlike other borer species, there is no larval diapause.

Sesamia inferens is another stem borer damaging millets in India and Africa (Gahan 1928; Tams and Bowden 1953; Krishnamurty and Usman 1952). Larval feeding first leads to leaf scarification and then to the production of shot holes. The 3rd instar larvae migrate to the base of the plant and bore inside leading to the production of a typical stem borer deadheart. In mature plants, the larvae bore the stems and make tunnels while feeding on the internal tissues. S. inferens is a serious pest of finger millet in southern India. Maize and sorghum are also attacked. The life cycle has been described in detail by Nair (1975). The life cycle is completed in 45-75 days and there are 4-6 generations per year. A female lays more than 400 eggs in batches of up to 160. The eggs are deposited between the leaf sheath and the stem in rows of 2-3, but may also be laid on the soil surface near the base of the plant. Under laboratory conditions, the females prefer leaves of E. coracana for oviposition than vertical sticks (Lingappa and Channabasavanna 1981). The eggs are round, creamy white, changing to brown before hatching. The egg stage lasts for 4-9 days in summer and 9-25 days in winter. After hatching the young larvae disperse to neighbouring plants but more than one larva may be found per plant. Larvae establish satisfactorily when placed in plastic boxes between the leaf sheath and the culm in E. coracana (Lingappa and Channabasavanna 1983). There are 5-7 larval instars, and larval development is completed in 3-4 weeks. The larvae also move from plant to plant, and may thus damage many plants during the course of their life. The full grown larva is pink in color with a dark brown head. Pupation takes place inside the larval tunnel or outside under the leaf sheath. The pupal period lasts for 5-12 days in summer and 12-36 days in winter.

## 2.2.3. FOLIAGE AND GENERAL FEEDERS

### 2.2.3.1. Grey Weevils and Leaf Beetles

Grey weevils, Myllocerus spp occasionally become serious on millets and have a wide distribution all over India. Among these, M. undecimpustulatus maculosus is a general feeder with an extensive range of host plants (Pande 1971). When the adult numbers reach outbreak proportions, the entire crop may be skeletonized. Light yellow colored eggs are laid in the soil. The grubs feed on the roots and remain in the soil. The damaged plants dry up or remain stunted (Plate 14). Larvae are stout, fleshy, yellow colored and about 7-9 mm long. Pupation occurs in earthen cells in the soil. Egg, larval and pupal periods last for 3-11, 32-42, and 5-7 days respectively. Total development is completed in 42-54 days. Adults are small weevils with whitish grey elytra (Plate 15). Leaf beetles (Lema spp and Chaetocnema spp) also result in severe damage occasionally during seedling stage in India and Africa (Nayar 1975; Ndoye et al. 1986).

### 2.2.3.2. Corn Leaf Aphid

Corn leaf aphid, Rhopalosiphum maidis is widely distributed in tropical and subtropical climates. It transmits maize streak virus disease, which may cause substantial yield losses (Brandes and Klaphaak 1923). Colonies of dark green to blue green aphids (Plate 16) cluster in the whorl leaves. Both adults and the nymphs imbibe the plant sap and under severe infestation, the leaves become distorted and plant growth is arrested (Nair 1975). The aphids also secrete honey dew which attracts ants and on which moulds grow. Population build up is rapid by parthenogenetic reproduction. Adults may be winged or wingless and are blue green in color.

2.2.3.3. Greenbug

Greenbug, Schizaphis graminum is a destructive pest of small grains (Dahms 1951). It is distributed between Canada to the Gulf States and the Atlantic to Pacific. It feeds on a number of graminaceous plants. The infested fields show deadened areas during late winter or early summer. Plants are infested with colonies of tiny green aphids, which while feeding, inject toxic saliva causing discoloration and tissue necrosis. Nymphs are pale green, and when fully grown, have a dorsal dark green stripe. In the warmer southern states of USA the winter is passed as active nymphal and adult stages while in the north, as the egg stage. The eggs hatch during early spring and females begin to produce nymphs 7-18 days after emergence. During the summer, nymphs may develop into winged or wingless adults each of which can give rise to 50-60 nymphs. With the approach of cold weather, winged males and females are produced, which after mating lay overwintering eggs (Davidson and Peairs 1966).

2.2.3.4. Spittle Bug

Spittle bug, Poophilus costalis is an occasional pest in Africa and certain parts of Asia. Adults and nymphs feed on leaves resulting in chlorotic spots. The plants become stunted in growth and produce smaller panicles. Adults are brown-grey in color. The nymphs remain inside a foamy spittle mass (Plate 17). Nymphs leave the spittle after last moulf and become active (Bonzi 1981).

2.2.3.5. Chinch Bug

Chinch bug, Blissus leucopterus causes severe damage to millets and other cereals in Central and North America (Reis et al. 1976; Davidson and Peairs 1966). The young bugs are bright red but become darker as they approach the adult stage. Females lay an average of 250 yellow-white eggs behind the leaf sheaths but sometimes in the soil at the base of the stem, and hatch in 1-3 weeks. The nymphs moult five times. There are two generations per year in USA. It is migratory in habit. The adults hibernate among the grasses in hedgerows, and along the edges of woodland (Davidson and Peairs 1966).

2.2.3.6. Shoot Bug

Shoot bug, Peregrinus maidis is pantropical in its distribution (Hill 1975) and is a vector of stripe disease of pearl millet and other graminaceous crops (Cherian and Kylasam 1936). The insect imbibes sap from leaves confining itself in the leaf whorls or on the inner side of leaf sheaths (Plate 18). The sucking of sap leads to leaf chlorosis, stunted growth, and ultimately, reduced plant population or shrivelled and chaffy grains. Its biology has been studied by Chelliah and Basheer (1965). The female makes a slit in the leaf midrib and inserts 1-4 eggs. A female lays about 100 eggs in 6-8 days. The nymphs are light brown in colour with prominent legs and wing pads. Adults are found in macropterous and brachypterous forms. Males are dark brown and females a yellowish brown. Egg, nymphal, and total life cycle last for 7-10, 16-18, and 18-31 days respectively. Adult longevity of macropterous forms is 16 and 43 days for males and females respectively. Brachypterous males and females live for 14 and 44 days respectively.

### 2.2.3.7. Sugarcane Leaf Hopper

Sugarcane leaf hopper, Pyrilla perpusilla (Plate 19) feeds on a number of graminaceous plants. Its main host is sugarcane, but high populations have also been recorded on pearl millet (Jotwani et al. 1969b). The insect sucks sap from the lower surface of the leaves leading to withering, which can adversely affect the grain yields (Kushwaha et al. 1980). Eggs are laid in batches of 30-50 in the leaf sheaths or on the lower surface of the leaf along the midrib. The egg clusters are covered with fine whitish hairs produced from the anal pads of the female. A female can lay 600-800 eggs in its life time. Adults are straw colored with a prominent snout. Egg incubation lasts for 7-10 days. Nymphal development is completed in 34-52 days, and the total life cycle takes 40-55 days. There are 3-5 overlapping generations in a year. The winter is passed in the nymphal stage in North India. The pest prefers broad leaved and succulent varieties (Jotwani and Butani 1978).

### 2.2.3.8. Grasshoppers and Locusts

Grasshoppers and locusts are occasionally serious pests of millets in India and Africa. The hoppers destroy seedlings and feed on leaves, and when the infestations are heavy, resowing may be necessary. The important species are Colemania sphenarioides, Hieroglyphus nigrorepletus, H. daganensis, Oedaleus senegalensis, O. nigeriensis, Schistocerca gregaria, Locusta migratoria, and Chrotogonus spp.

Colemania sphenarioides is a serious pest in South India (Subramanyam 1941). The insect feeds on the foliage and may also devour the florets and ripening earheads (Plate 20). Under a severe infestation, the crop may be completely destroyed, and need to be resown. Adults are wingless, yellow-green in color with a lateral purple band. There is only one generation per year. Eggs are laid during September-October in batches of 30-60 below the soil surface. A female may lay from 60 to 100 eggs during its life time. The eggs hatch with the onset of monsoon during June-July. The nymphs undergo 5-6 moults and become adults in 10-12 weeks (Nair 1975).

Chrotogonus trachypterus is the common surface grasshopper in India (Kevan 1954), and is a serious pest in some years. The eggs, which are laid in the soil, hatch in 15-days in the summer and 150 days in the winter. There are 5-7 nymphal instars which complete the development in 40-170 days. There are 2-6 generations per year depending on the region and climate. They become sexually mature in 2-7 days and can live for long periods.

Hieroglyphus nigrorepletus is a serious pest in North India (Roonwal 1945; Peshwani 1960). Heavy incidence has been reported from Rajasthan (Jotwani and Butani 1978). The adults and nymphs feed on leaves, leaving the midribs intact, and may also feed on the earheads. A female may lay 3-6 egg pods, each containing 25-50 eggs which are yellow-pink in color. Normally eggs are laid in September-October and hatch during the following June-July, but they may remain viable for upto three years. The nymphs mature in 3-5 months. Adults hibernate among grasses or other wild hosts (Roonwal 1945).

Oedaleus senegalensis becomes occasionally important in Africa (Mallamaire 1948) and India (Bhatia and Ahluwalia 1962 and 1966). All stages of the crop may be damaged, put most loss occurs during seedling stage. Adults are green-brown in color. It is a migrant species. Nymphal development is completed in nearly 2 months. It diapauses in egg stage, which may last up to one year. Breeding occurs during rainy season.

Zonocerus variegatus is a common grasshopper in Africa. Nymphs and adults are observed in groups on various crops. It has only one generation per year. Eggs are laid in September-October at the end of rainy season. Eggs hatch at the beginning of next rainy season in March-May. Adults and nymphs live for nearly 6 months. .p

The desert locust, Schistocerca gregaria adults in solitarious phase are light yellowish-grey while those of gregarious phase are lemon yellow. It is widely distributed in semi-desert regions of Africa and Asia (Schmutterer 1969). It is a highly polyphagous insect during gregarious phase and feed on a number of plant species except Azadirachta indica A Juss Hopper bands do considerable damage during their development, but most severe losses are caused by young adults when they leave the breeding sites and the swarms invade new areas. Heavy damage to crops occur during outbreaks, which occur at regular intervals. Regional and international campaigns have put a break on the regular occurrence of locust outbreaks. The females lay eggs in damp sandy soils at a depth of 6-8 cm. Eggs are laid in masses of 20-100, and a female lays 60-160 eggs. Egg incubation takes 10-15 days, but varies according to temperature. Nymphal development is completed in 6-7 weeks. Hoppers are able to fly two days after the final moult. During night the hoppers roost on shrubs, trees, and grasses. The hoppers take to wings after sunrise at 17-23 deg C and the swarms fly along the wind. Rain showers and a fall in temperature (<23 deg C) causes the swarms to settle on the ground.

The African migratory locust, Locusta migratoria is widely distributed in tropical Africa south of Sahara. Adults of solitarious phase are greenish brown while those of gregarious phase are yellowish-brown. It is polyphagous but distinctly prefers wild and cultivated Graminea and doughstage grain of pearl millet and other grain crops. Its swarms coincide with those of S. gregaria in these areas. The females lay eggs at the beginning of rainy season in the soil. A female lays 100-200 eggs. Eggs hatch in 4 to 21 days. Young hoppers of the gregarious phase congregate and begin to march. When soil temperature exceeds 27-28 deg C. The nymphal development is completed in a few weeks. The adult swarms begin to fly at 26-27 deg C and may fly distances of more than 1500 km. Its bionomics and behaviour during the gregarious phase is quite similar to that of S. gregaria. Biology and general migratory behaviour of locusts has been studied by Rao (1925) and Uvarov (1966, 1977).

2.2.3.9. Hairy Caterpillars

Bstigmene lactinea, Prothesia xanthorhoea, Amsacta moorei, and A. meloneyi are the major hairy caterpillars which damage millets.

The red hairy caterpillar, Amsacta moorei is a polyphagous pest and causes considerable damage to pearl millet occasionally (Yadva et al. 1966). The caterpillars are voracious feeders on leaves and the entire crop may be destroyed if a severe infestation occurs during an early growth stage (Parihar 1979)(Plate 21). The moth has white wings with red margins. A female lays up to 1500 yellow white eggs in clusters of 97-880. The egg incubation period lasts for 2-4 days. On hatching , the young caterpillars remain congregated at one place and disperse after 12-days. Larval development is completed in about 2 weeks. The caterpillars are highly active and may move from field to field in large numbers. The fully grown caterpillars are deep orange in colour with a dense covering of long hairs all over the body. The insect pupates in the soil in a cocoon incorporating larval hairs. The adults emerge during the following June-July at the onset of the monsoon. There is only one generation per year. This pest is most active in the field during July-August (Nair 1975; Jotwani and Butani 1978; Verma 1980). Amsacta meloneyi is widely distributed in West Africa. The moth is silvery white with a yellow abdomen, and dark stripes along the veins of fore wings. Hairy larvae feed on weeds and a number of cultivated crops. It has only one generation per year. Its damage is severe occasionally.

Black hairy caterpillar, Estigmene lactinea occasionally becomes a serious pest of pearl millet in South India (Fletcher 1914). Among the millets, finger millet is particularly susceptible to damage (Nair 1975). The adult is a large white moth with crimson markings on the head, body and wings. The eggs are laid on the plants. The caterpillars, 48-52 mm long, are black with reddish brown hairs arising from the urats. They pupate in an earthen cell in the soil. Caterpillars feed on the leaves and may kill the seedlings.

Tent hairy caterpillar, Prothesia xanthorhoea (Euproctis virguncula) has been noted as a pest of pearl millet by Vaish and Sharma (1971) and Sandhu et al. (1974c). The female moth lays 100-150 creamy white eggs which are covered with yellow hairs, and hatch in 3-4 days. The larva moults 5 times. The larval and pupal stages are completed in 31-39 and 9-11 days respectively. There are three generations a year. Peak larval activity occurs during August and September (Vaish and Sharma 1971).

2.2.3.10. Armyworms

Mythimna separata, M. loreyi, Spodoptera exempta, S. exigua, S. littarolis, and S. frugiperda become occasionally serious on pearl millet in India, Africa, and Northern America. During periods of heavy out breaks, the entire crop is skeletonized.

Oriental armyworm, Mythimna separata is an important millet defoliator in Asia (Plate 22). A female lays about 900 eggs, to a maximum of 1940 (Hamblyn 1959; Hsia et al. 1963). The egg incubation period lasts 2-7 days (Avasthy and Chaudhary 1965). Larval development is completed in 14-22 days (Puttarudriah and Usman 1957; Avasthy and Chaudhary 1965; Cadapan and Sanchez 1972; Dwijendra Singh and Rai 1977), and the pupal stage lasts for 8-9 days (Avasthy and Chaudhary 1965; Dwijendra Singh and Rai 1977). Total development takes 26-38 days (Avasthy and Chaudhary 1965; Cadapan and Sanchez 1972; Dwijendra Singh and Rai 1977). The adults emerge between 20.00-23.00 hr (Anon. 1976) and survive for 4-5 days (Avasthy and Chaudhary 1965). Mating occurs on the 3rd and oviposition on the 4th day after emergence (Kanda and Naito 1979). The full grown larvae prefer high humidity (Bindra and Singh 1973). Survival is higher on heavily manured crops (Koyama 1966). Tanaka (1976) and Patel (1979) have studied the feeding rhythm of the larvae. Feeding normally occurs during the night. The larvae hide in cracks during the day.

Adult populations can be monitored with light traps (Spitzer 1970; Persson 1977) or molasses-baited traps (Koyama 1968). The rate of oviposition can be determined by using dry leaves of sorghum (Tanaka et al. 1971). Spitzer (1970) observed moth activity during winter in New Zealand and concluded that there is no winter diapause in the life cycle of this insect. The larvae were present in the field throughout the year in Punjab (Bindra and Singh 1973; Anon. 1974). However, Atwal (1976) reported that the larval period was as much as 88-100 days in Punjab during winter. Heavy rains followed by a prolonged period of drought result in heavy outbreaks (Sharma et al 1982; Morey et al 1983).

The African armyworm, S. exempta is an occasional pest of millets in Africa. Its outbreaks occur periodically and results in extensive damage to cereals and pasture grasses. The larvae are gregarious during the outbreaks. The eggs are laid in batches on the under surface of leaves, which hatch in 3-4 days. The larval period lasts for 10-20 days. Pupation takes place in soil, and the adults emerge in a weeks time. Adults migrate at night for long distances.

Outbreaks are associated with rainy season, and in eastern Africa, there is a northward progression from Tanzania to Ethiopia (Schmutterer 1969).

The fall armyworm, Spodoptera frugiperda defoliates millets in the American continent (Escalante 1974; Piedra 1974). The outbreaks are severe in Southern and Central America and Mexico and may become abundant in late summer and fall in the Southern United States. It has a wide host range. Eggs are laid in masses during the night on grasses and graminaceous crops. The egg incubation period lasts for 2-10 days. Six larval instars complete their development in about 20 days. Pupation takes place in the soil, the pupal stage lasting about 10 days. Female moths may migrate several km before they lay eggs. There are several generations in the southern United States and in South America. Under conditions of scarce food supply and high densities of larvae, the insect behaves as an armyworm and assumes a much darker coloration. Larvae have an inverted Y-shaped suture on front of the head, and the body has long hairs arising from black tubercles. Males have dark grey brown forewings mottled with light and dark spots and greyish white hind wings. The forewings of female are uniform grey (Davidson and Peairs 1966).

Cotton leafworm, Spodoptera littoralis feeds on pearl millet in Africa (Hill 1975). The forewings are dark brown, marked with light colored lines and stripes, and the hind wings are whitish with dark brown margins and brown venation. The Larvae are light green, but later turn blue-green. Later instar larvae are dark-grey. The larvae pupate in an earthern cell. A female lays about 1000 eggs with a maximum of 3700. Young larvae are sensitive to high temperatures and low humidity. Larvae feed during the night on the leaves of a wide range of host plants (Avidov and Harpaz 1969).

### 2.2.3.11. Leaf Roller

Leaf roller, Marasmia trapezalis is a sporadic pest of sorghum in India but also feeds upon pearl millet. The adult moths are slender, brown with waxy brown markings on the forewings (Jotwani and Butani 1978). The eggs are laid on the upper surface of leaves and the larvae feed on the inside surface of a folded leaf (Plate 23). The larva is slender, pale yellowish green in colour, and about 20 mm in length, it has small oval spiny patches scattered over the body, from which stout bristly hairs arise. The larvae are fully grown in 11-20 days. Pupation occurs within a leaf fold, and is completed in 6-8 days. As a result of larval feeding, the leaves start drying up from the tips. Broad leaved and succulent varieties are highly susceptible (Nair 1975; Srivastava et al. 1970)

## 2.2.4. EARHEAD PESTS

### 2.2.4.1. Pearl Millet Midge

Pearl millet midge, Geromyia penniseti is an important pest of pearl millet (Plate 24). It is widely distributed in South India, Sudan, Uganda, Nigeria, Niger, Upper Volta, Ghana, Senegal, and Madagascar (Coutin and Harris 1968; Santharam et al. 1976). Its detailed biology has been studied by Coutin and Harris (1968). Felt (1920) described it from India and named it Itonida penniseti. The midges emerge after sunset and are most active for 3 hrs before and 1 hr after midnight; by 04.00 h, all activity ceases. The eggs are inserted either into the space between spikelets and the involucre of bristles or, more usually, between two spikelets. The eggs are elongate and slightly curved and stuck to the glumes or to the strong bristles. The female midges show a marked preference for millet heads in which the female flowers are fully open and the stigmas have not yet emerged. Eggs hatch in 3 days and the larvae crawl over the spikelets to the ovary, on which they feed. Sometimes the glumes may separate, revealing the larva inside. Larva pupates within the flower. The pupal stage lasts for about 2 days and adults emerge at 18.00 h with the peak emergence at 19.30 h. By looking at infested heads against the light, the pupae may be seen emerging from the floral cavity by twisting movements of the abdomen. Males generally emerge before females and wait for them on the heads.

G. penniseti is strictly nocturnal and thus easily overlooked. Development from egg to adult takes about 13 days at a mean temperature of 29 deg C. Four to five overlapping generations develop during the wet season. Towards the season end, the population levels decline due to larval parasitization. The proportion of diapausing larvae varies from 0.7 percent at the beginning of the season to about 10 percent at the end of the season. These proportions are much lower than those observed for C. sorghicola Coq. (Coutin and Harris 1968).

2.2.4.2. Blister Beetles

Species of the genera Mylabris, Cyaneolytta, Cylindrothorax (Plate 25), and Psalydolytta feed on millet blossoms in India and Africa. Commonest among them is Mylabris pustulata (Ramamurthy et al. 1970)(Plate 26) in India. The adults are conspicuously bright metallic blue, green, black and red-yellow or brown. The insect numbers are higher in the later half of the monsoon season. The detailed biology of these insects has not yet been worked out. The adults feed on inflorescences and results in poor seed set. The damaged florets become light brown in color. When disturbed, the beetles produce an irritant fluid called cantharidine. Eggs are laid in large numbers in the soil. The triungulin larvae feed on eggs of other insects and undergo hypermetamorphosis. The adults are general feeders on flowers of many plant species.

2.2.4.3. Chafer Beetles

Chafer beetle, Chiloloba acuta is primarily a pest of cotton, but has become a potential pest of pearl millet in Uttar Pradesh. It feeds on the inflorescences. The insect is elongate, green and with yellow hairs (Srivastava et al. 1971a)(Plate 27). Oxycetonia versicolor (Plate 28) is another important pest feeding on pearl millet inflorescences (Verma 1980). The adults feed on the pollen and stigma and result in poor seed set. Adults of the genera Pachnoda, Anomala, and Rhinyptia also feed on the developing grain in large numbers (Verma 1980; Gahukar 1984; Ndoye et al. 1986). Pachnoda fairmairei feeds on developing grain (Plate 29). Pronotum in yellow in color except for two large oblong black areas and two small dark submarginal spots. Elytra are yellow with a number of dark spots. P. interrupta is blackish in color. Pronotum and elytra bear yellow-brown or reddish brown margins and a number of spots and strips of same color. Adults feed on ripening grain. Rhinyptia reflexa has been reported to feed in large numbers on inflorescence and ripening grain in West Africa.

2.2.4.4. Dusky Cotton Bug

Dusky cotton bug, Oxycarenus leatus is a potential pest of pearl millet in India. The adults are dusky colored and the nymphs reddish brown. Both the adults and nymphs suck sap from the grains. The egg incubation period lasts for 6-10 days and nymphal development is completed in 15-20 days (Nair 1975). Spilostethus, (Plate 30) and Aphanus also become serious on developing grain.

2.2.4.5. Earhead Bugs

Earhead bug, Calocoris angustatus is primarily a serious pest of sorghum, but it also feeds on millets in India (Plate 31). Both the adults and the nymphs imbibe the sap from tender portions of the plant as well as from un-ripened earheads when the grains are in the milky stage. During heavy infestations, a large number of bugs cluster around the earheads and the affected earheads become chaffy and do not contain normal healthy grains. In about 14 days, a female deposits 150-200 eggs under the glumes or in young florets. The eggs are pale green in colour, cigar shaped and hatch in 5-7 days. Nymphal development is completed in 15-17 days. There are usually two generations during the crop season (Ballard 1916). Other mirid bugs reported to be feeding on pearl millet panicle are Creontiades pallidus, Eurystylus bellevoyei and Campylomma sp. (Sharma and Davies 1982).

2.2.4.6. Stink Bugs

Stink bug, Bagrada cruciferarum is a major pest of cruciferous plants, but recently, serious infestations have also been reported on pearl millet (Sandhu et al. 1974b; Tayade et al. 1976). It is widely distributed in Asia and Africa. The adults and nymphs suck sap from the leaves and developing grains. The adults are black in colour and painted beautifully with yellow red spots on the back. The eggs are laid in clusters on the soil, on leaves or earhead. A female lays 15-20 eggs/day and about 250 eggs during its life. The eggs hatch in 5-7 days. Young nymphs are bright orange in colour. (Plate 32) There are five nymphal instars, and development is completed in three weeks, the entire life cycle taking 4-5 weeks. There are about 9 generations per year (Atwal 1976).

Green stink bug, Nezara viridula (Plates 33) feeds on the leaves and the developing grains (Reddy and Davies, 1979). It is green colored. The anterior part of head and pronotum is yellowish white.

It is widely distributed in tropical and sub-tropial regions. It is polyphagous. Nymphs and adults suck sap from the developing grain or other tender parts of the plant. A female lays 100-200 eggs in groups on leaves or the panicle. Eggs hatch in 4-5 days and nymphs become adults in 4-5 weeks. There are several generations in a year. Adults spend the dry season in protected places.

Shield bug, Agonoscelis pubescens (Plate 34) is yellowish brown with numerous dark spots. It is widely distributed in Africa. It feeds on developing grain which become shrivelled or atrophied. Nearly 20 bugs can destroy the entire panicle. During dry season, the adults shelter in clusters on stems and branches of trees and bushes. Eggs are laid in clusters on leaves or inflorescences. Eggs hatch in 3-4 days and nymphs complete development in 3-4 weeks. At the end of season, the bugs move in search of shelter in trees, bushes, and weeds (Schmutterer 1969).

2.2.4.7. Gundhi Bug

Gundhi bug, Leptocorisa acuta occasionally feeds on pearl millet, but it is best known as a major pest of rice and has wide distribution in Asia and Australia. Infested grains become yellowish brown and ultimately dry up. The presence of a foul smell in the field indicates the presence of this insect. The insect lays about 100 dark red eggs near the midribs of the leaves. The nymphs are yellow green whilst the adults are brown dorsally and green ventrally and have slender legs. Egg and nymphal development is completed in 5-8 and 15-20 days respectively. The insect hibernates in the adult stage (Jotwani and Butani 1978).

2.2.4.8. Spotted Stainer Bug

The spotted stainer bug, Dysdercus superstitiosus (Plate 35) occasionally becomes serious on pearl millet panicles in Africa. Color of nymph changes from yellow to orange and red as it grows. It has a wide host range. Adults and nymphs feed on developing grain. Grains show distinct feeding punctures and remain shrivelled. It migrates between different host plants. Eggs are laid in batches in the soil mainly near the stems. A female lays 300-400 eggs. Eggs hatch in 4-14 days. Nymphal development is completed in about 25 days. Two or more generations may develop on one crop in a season (Schmutterer 1969).

2.2.4.9. Earhead Worm

Earhead Worm, Eublema (Autoba) silicula has been observed to be a serious pest on some pearl millet varieties in India (Jotwani et al. 1966)(Plate 36). The caterpillars feed on the maturing grains, remaining hidden under a small dome-shaped or elongated gallery formed from silk and anthers (Nair 1975). The greenish white eggs are elongate and oval. The caterpillars are hairy and brownish yellow in color. The forewings of the adult moths are reddish-buff colored with 3 dark spots on the anterior margin. The egg, larval and pupal periods last for 4, 12-13, and 12 days respectively (Taley et al. 1974). Adult longevity is 4-5 days for males and 14-15 days for females. E. gayneri and Pyroderces simplex also become serious pests on pearl millet panicle in India and West Africa (Ndoye et al. 1986).

2.2.4.10. Earhead Caterpillars

Gram pod borer, Heliothis armigera is a well known, very serious and polyphagous pest of a number of crops. Its biology and seasonal activity has been studied in detail on pulses, tomato and other crops. This pest is widely distributed in old world and Australia. Recently, its high incidence has been reported on pearl millet (Vishakantaiah 1972). High damage has also been recorded at the ICRISAT farm during the rainy season (Sharma and Davies 1982). The eggs are laid singly all over the head. A female lays 200-300 eggs, which are creamy white in colour and hatch in 4-6 days. There is a large amount of color polymorphism among the larvae. The larvae feed on developing grains (Plates 37 and 38), and complete development within four weeks. The larvae pupate in the soil and the adults emerge after 2-4 weeks.

The earhead webworm, Cryptoblabes gnidiella, has also been reported as a serious pest of hybrids and high yielding varieties of millets. The eggs are creamy white, ovoid, flat, and laid on the spikelets and tender grains. Caterpillars are dark brown in color. The adults have dark grey forewings and the hindwings are fringed with hairs on the anterior margin, and are bigger than the forewings (Jotwani and Butani 1978). Egg and larval periods last for 3-4 and 9-10 days respectively. Longevity of males is 3 days and that of the females 5-6 days. The entire life cycle lasts for 22-24 days (Taley et al. 1974; Srivastava and Singh 1973).

C. angustipennella is a serious pest of finger millet in South India. The eggs are laid on newly opened flowers or other parts of the inflorescence. A female lays about 14 eggs in 3 days. Egg, larval and pupal periods last for 3, 19-22, and 7-20 days respectively. The life cycle is completed in 31-43 days (Nair 1975).

The pearl millet head caterpillars, Masalia spp and Raghuva spp are the most important panicle feeding insect pests in Africa. In addition, other insects such as Eublema gayneri, Heliothis armigera, and Pyroderces sp. have also been recorded (Anon. 1982; Schmutterer 1969). They cause 25-50 percent loss of grain every year(Vercambre 1978). However, the relative importance of Raghuva and Masalia is not very clear from the available literature. According to Ndoye (1979), R. albipunctella is the most destructive species on pearl millet (Plate 39). He states that no species of Masalia found in Senegal have been recorded as a pest of cultivated plants. However, references to the genus Masalia have been made since 1973, when the borer became a problem after a period of drought. Vercambre (1976, 1977 and 1978) has referred to these head borers of pearl millet as Raghuva spp and Masalia spp.

The first adults of Raghuva sp appear a month after the first rains, and emergence continues over 5 weeks. The eggs are usually located on the involucral bristles of the millet flower. Sometimes, the eggs are also laid directly on the rachis. The young caterpillars perforate the glumes of flowers and feed in the interior portion. Presence of the insect at an early stage can be detected by the excreta seen around the damaged flowers. In the later instars, the caterpillars cut the floral peduncle with their mandibles, preventing grain formation. They shelter between the rachis and flowers, and the head is damaged in a spiral manner (Vercambre 1976). The caterpillar is quite squat, yellow to dark green in color with two light bands on each side extending from the head to the last segment. Before pupation, the larva becomes light red in color. In the case of Masalia sp, the egg and larval periods last for 4 and 28 days respectively under natural conditions (Vercambre 1976; 1978). The pupal period varies greatly depending upon whether the insect enters diapause or not. Adults emerge in 12-24 days from the non-diapausing pupae, whilst the diapausing ones may take nearly 11-12 months (Vercambre 1978). There is one generation per year. The insect pupates in the soil during the dry season. Females start ovipositing on the flowers one month after the first rains (Vercambre 1977) and each female is capable of laying 400 eggs. The moth is greenish in color with five white longitudinal stripes.

### 2.2.4.11. Blossom Thrips

Blossom thrip, Thrips florum is the most common species infesting the inflorescences of pearl millet. The insect has an extensive host range. Other species infesting pearl millet are Haplothrips ganglbaueri and H. gowdeyi (Black thrips). High densities of thrips have been observed at ICRISAT Center, causing a large number of florets to remain undeveloped and giving rise to erratic seed set in some genotypes (Plate 40). Genotypes with compact heads suffer less damage (Sharma and Davies 1982).

## 2.3. CONTROL MEASURES

Little effort has been made in the past to develop proper management practices for insect pests of millets, and much remains to be done. The relative pest free status of millets in India should not lead to complacency over the possibility of future pest problems. With the introduction of high yielding cultivars and improved crop husbandry practices, the role of insects in millet production may change dramatically. It is therefore, essential to clearly examine present knowledge of existing and potential pests and begin thinking in terms of developing economic and realistic pest management strategies.

Currently, the control of millet insect pests involves the occasional use of insecticides and some cultural operations to reduce insect damage. Very little attention has been paid to the possibility of host-plant resistance and other methods of insect control. Unfortunately, millet growing farmers cannot afford recommended insecticides for insect control and that their use is uneconomical under existing levels of production. However, under experimental conditions, or under very high levels of infestation on farmers' fields, the chemical control may become necessary to avoid serious crop losses. The SAT farmers' capacity to sustain crop loss is very low and they cannot afford to loose even a small portion of their produce. The socio-economic realities must be borne in mind when developing insect pest control strategies for millets in the SAT, and special attention must be given to low cost control measures. This can be achieved by the integration of cultural and natural control, and host plant resistance, with lower emphasis on chemical control, which the farmers can least afford.

The effectiveness of integrated control lies in its widespread application over large areas, and therefore, cooperation among the farmers in a village or a geographical unit is most important. However this, at times is difficult to achieve. Timely sowing of crops, deep ploughing of fields after harvest, crop rotation, and crop combinations unfavourable to certain insect pests, and planting of pest resistant cultivars can go a long way in reducing insect damage. However, during heavy outbreaks, these control measures may not be effective in controlling insect pests. Under high population pressure, even resistant genotypes may suffer heavy damage. Continuous and widespread planting of a single resistant genotype may also lead to the evolution of an insect biotype capable of feeding and multiplying on it. Efforts to breed resistant varieties must therefore place adequate emphasis on studying the mechanisms of resistance and breeding for multigene horizontal resistance. Insecticides may be used as a last resort to control pest outbreaks. A rational combination of cultural methods, natural enemies, and resistant genotypes (which are compatible with each other) to a large extent can maintain pest populations below economic thresholds.

### 2.3.1. CULTURAL CONTROL

Cultural methods of pest control involving crop husbandry practices such as crop rotation, intercropping, sanitation and crop refuse destruction, planting and harvesting dates, trap crop planting, soil tillage, fertilizer use, water management, thinning, and planting geometry are the most important and effective pest control components in integrated pest management. Any modifications in the prevailing crop production practices to create plant and environmental changes inhospitable to the insects is an important component of pest control. Cultural practices are one of the oldest pest control practices, and are relevant to the subsistence farming systems of the SAT. The most important advantages of these practices is their low cost and there are no adverse effects on the environment.

However, despite their relevance and importance to the SAT, very little has been done to make them appreciable for pest control in pearl millet. This aspect of pest control should receive more attention than some of the more sophisticated high cost pest control technology such as pheromones, hormones, chemosterilants, and the never synthetic insecticides.

The following crop husbandry practices have been found to be useful in reducing insect numbers and hence insect damage in pearl millet.

#### 2.3.1.1. Intercropping

Intercropping pearl millet with pigeonpea or sunflower has been shown to reduce the white grub damage (AICMIP 1975-76). Intercropping pearl millet with sorghum reduces the damage by *B. fusca* in sorghum. However, intercropping pearl millet with sorghum or maize does not reduce the damage by *A. ignefusalis* in pearl millet (Adesiyun 1985).

#### 2.3.1.2. Crop Rotation and Sanitation

Field sanitation, and uprooting and burning of stubbles helps to reduce the carryover of stem borers. Stalks kept as animal fodder should be fed before the onset of monsoon rains (Jotwani and Butani 1978). Partial burning of pearl millet stalks immediately after harvesting destroys 61-84% of larvae and 98-100% pupae of *A. ignefusalis* (Ndoye et al. 1986). Piling and burning of the trash at dusk in the fields attracts and kills white grub adults leading to reduction in oviposition (Yadava et al. 1973). Making fire around pearl millet fields to attract and destroy blister beetles is a common practice in the Sahel (Ndoye et al. 1986).

#### 2.3.1.3. Tillage

Field tillage before planting and after the crop harvest helps to expose the hibernating/aestivating/hiding larvae and pupae of many insect species. Deep ploughing is particularly helpful in reducing the populations of grasshoppers, and hairy caterpillars (Jotwani and Butani 1978), and millet head caterpillars, *Raghuva* spp (Vercambre 1978).

#### 2.3.1.4. Planting Date

Early and timely planted crops escape the damage by many insect pests. The early planted crop is less damaged by the millet shoot fly (Sharma and Davies 1982). Planting of photosensitive cultivars or delayed planting of short duration varieties has been reported to reduce the damage by head caterpillars (Vercambre 1978; Ndoye et al. 1986).

#### 2.3.1.5. Mechanical Collection and Destruction

Egg masses of hairy caterpillars and other lepidopteran pests can be hand collected and destroyed. Aphid infestations can also be reduced by uprooting and destruction of the infested plants. Blister beetles can be collected by hand and destroyed (Jotwani and Butani 1978). Head bugs and other external feeders on the earhead can be dislodged into a bucket containing water to which kerosene has been added (Nair 1975).

#### 2.3.1.6. Weed Control

Proper and timely weeding of the crop reduces the damage by *Mythimna* separata (Sharma and Davies 1982) and Spodoptera spp (Ndoye et al. 1986). A clean crop is often less hospitable to insects as the weeds can provide hiding and oviposition sites for some insects. However, in certain situations, plowed fields have been reported to suffer higher damage than the no-tillage systems (Shenk and Saunders 1981). Weeds (Digitaria sp and E. indica) tend to harbour larvae of S. frugiperda and increase crop damage (Huis 1981).

2.3.1.7. Fertilization

Nitrogen fertilization improves plant vigour and reduces damage by the head caterpillars (Gahukar 1985). However, in some cases (e.g. stem borer damage) the fertilizer application may increase insect damage.

## 2.3.2. NATURAL CONTROL

Natural control as defined by Huffaker et al. (1971) is the maintenance of population numbers within certain upper and lower limits by the action of the whole environment, including an element which is dependent on pest density. It is the combined action of both the biotic and abiotic environment that maintains the population of many species at a characteristic, yet fluctuating level. Abiotic factors act independently of density whereas most biotic factors are density dependent.

Present knowledge and the scope for biological control of millet insects has been reviewed in this section. The term 'Biological Control' is used in the context of the conservation and enhancement of existing parasitoids and predators already available by manipulation of their environment in a favourable way. At the moment, the applied or the classical biological control through importation, colonization, mass culture, and release of exotic natural enemies is not relevant because of the nature of the crop environment, crop duration, and the existing knowledge of the host parasite interactions.

Knowledge of the biological control agents of millet insects is very limited and scanty and this is probably due to the lack of efforts made in the past, the localized nature of pest problems, and the subsistence nature of millet farming. However, a number of parasites and predators have been recorded from millet pests, which are also pests of other cereals. A list of the parasites/predators recorded only from the millets has been made, since the natural enemy complex varies in different crops and crop combinations (Bhatnagar and Davies 1979b; Ashley et al. 1980; Sharma et al. 1982). The available information on the beneficial organisms on millets is summarized in Table 4. The reports from Harris (1962), Nair (1975), and Reddy and Davies (1979) also include the collections made from other cereals.

## 2.3.3. HOST-PLANT RESISTANCE

Plants that are inherently less damaged or less infested by phytophagous insects under comparable environments in the field are termed resistant (Painter 1951). Resistance as expressed in the field is usually complicated involving in most instances, all the three components of resistance viz. antixenosis (non-preference), antibiosis, and tolerance. In addition, there are many interactions between the plants, the insects, and the environment. The insect is dependent upon the plant for much more than the basic nutritional requirements. To be acceptable as a host, the plant must provide the necessary visual, chemical, and physical stimuli, and a favourable micro-environment for development and reproduction in addition to the basic nutritional requirements. It is in this context that we shall look at millets as host plants to the insects feeding upon them.

2.3.3.1. Intespecific Resistance/Preference

Pearl millet is grown as a short duration crop in most of the semi arid regions, although long duration photosensitive cultivars are also grown on a large scale in many of the drier regions of West Africa. Thus, the susceptibility periods of different developmental stages of the plant are relatively shorter than those of the most other cereals. The millets characteristically have the C4-dicarboxylic acid pathway of carbon fixation, which as a general rule, makes the crop a poorer food source for insects and other herbivores, as compared to the C3-Calvin cycle pathway. The C4 species have two to three times higher rate of photosynthesis, particularly at high temperatures (30-40 deg C) and high light intensities (3000-5000 Candles), and require half as much water as C3 species to produce one unit of dry matter (Price 1975). There is a general tendency for insects to avoid C4 species as they are a poorer food source for survival and reproduction (Casewell et al. 1973). In C4 species, the starch is stored around the vascular bundles, the veins are overlaid with silica, the nitrogen content is lower, and lignin content is higher. It is for these reasons that millets do not have serious pest problems, although nearly 500 pests have been reported to feed on them, only a few species (<25) are known to have attained the status of a pest. Moreover, a large part of the acreage under millets is still covered by local landraces, which might have become less susceptible due to natural selection over a long time.

Kroh and Beaver (1978) observed 13 insect species feeding on monocultures of Amaranthus retroflexus, Chenopodium album, Panicum milliare, and Setaria viridis. Their observations indicated that insects (especially Hemiptera) tended to avoid plant species with the C4 photosynthetic carbon-fixation pathway. Among the different millet species, Brachiaria decumbens was found to be less susceptible to insect pests than Digitaria decumbens (Loch 1978). Echinochloa crusgalli var. oryzicola is resistant to Nilaparvata lugens because of the presence of trans aconitic acid (Koh et al. 1977).

Different species of shoot flies show marked preference towards different millets (Jotwani 1977). Pearl millet exhibits antixenotic resistance towards shoot fly (Atherigona sp)(Jotwani et al. 1969c). The sorghum shoot fly, Atherigona soccata shows preference to Sorghum vulgare compared with Digitaria scalorum, Setaria verticillata, and

*Panicum maximum* (Ogwaro 1978). Pearl millet is less favourable for the development of *Chilo partellus* whereas sorghum and maize are suitable (Pant et al. 1961; Kalode and Pant 1967; Ahmed and Young 1969; Singh and Tiwari 1979). Under field conditions, Ahmed and Young (1969) and Fletcher and Ghosh (1920) have shown that pearl millet is resistant to larvae of *C. partellus* during the early growth stages, but in the later stages, it is as vulnerable to internodal tunnelling and injury as sorghum. Some antibiotic factors in the leaves of pearl millet are suspected of being responsible for larval mortality in the early growth stages (Ahmed and Young 1969). In monocultures of sorghum, maize, and pearl millet, the African sorghum stem borer, *B. fusca* laid maximum eggs on sorghum, followed by maize, and pearl millet. The inability of *B. fusca* to lay eggs on pearl millet reduced the stem borer damage in sorghum when intercropped with sorghum. However, intercropping pearl millet with sorghum or maize did not reduce the damage by millet stem borer, *A. ignefusalis* (Adesiyun 1983).

The desert locust, *S. gregaria* is one of the insect species reported to show preference for pearl millet (Rao 1938; Bhatia 1940); on which the hoppers develop rapidly. Jackson et al. (1978) reported that pearl millet and some weed species (*Dipterygium glaucum*, *Tribulue longipetalus*, and *Chrozophora oblongifolia*) supported rapid hopper growth. Pearl millet and sorghum tended to enhance the gregarious habits while *D. glaucum* accentuated solitarious ones. In the gragarious phase, adults exhibit a preference for seeds (Haroon Khan 1945). The painted bug, (*B. cruciferarum*), primarily a pest of cruciferous and leguminous crops, has been reported to exhibit a preference for pearl millet (Gupta and Gupta 1970; Sandhu 1975; Sandhu et al. 1974b).

Pearl millet also shows antixenosis towards *C. trachypterus* (Gupta 1972). Boys (1978) studied the food selection behaviour of *O. senegalensis* in grassland and millet fields and found that the grasshoppers were feeding opportunistically on pearl millet. Conditioning was apparently important to the acceptability of various grass species. In the millet fields, the majority (80.9%) of grasshoppers fed only on millet. The adults were graminivorous and generally monospecific feeders. At first, most damage occurred on leaves and later, both leaves and heads were damaged. From field and laboratory observations, it was concluded that pre-milky and post-milky heads were rejected after palpation and only the milky heads and leaves were eaten. The males preferred leaves to seeds and females showed preference for milky seeds, this difference is probably due to the higher protein requirement of females for producing eggs. *H. banian* shows preference for sorghum followed by pearl millet. *D. sanguinales* is less preferred (Vyas et al. 1983).

In oviposition and feeding tests, Murdoch and Tashiro (1976) found that *H. licarisalis* did not show oviposition preference when a number of grass species were offered to it. However, lower numbers of moths emerged on *P. clandestinum* (Kikuyu grass).

Hackerott and Harvey (1970) studied the resistance of different millet species (P. americanum, S. italica, and P. miliaceum) to green bug, S. graminum. Millets were less suitable for survival and development than sorghum, and pearl millet seedlings were more resistant than mature plants. Among all the millets, P. americanum supported most green bugs and P. miliaceum the least, however, Pearl millet is more resistant than sorghum (Stegmeier and Harvey 1976). Under laboratory conditions, S. glauca and E. indica were found to be tolerant to chinch bug, B. leucopterus leucopterus and S. faberii was highly susceptible (Ahmad et al. 1984).

Pearl millet has been shown to exhibit antixenotic resistance to red hairy caterpillar, A. moorei (Pandey et al. 1970). A resistant genotype of pearl millet (No.240) has been found to reduce adult emergence and the size of adults of S. frugiperda (Leuck 1970). The effects of resistant pearl millet inbreds on the development of S. frugiperda larvae could probably present factors important to its natural control. The 'tr' gene (trichomelessness) significantly reduced foliar feeding by first and second instar larvae of S. frugiperda (Burton et al. 1977). Burton et al. (1977) also observed that fewer eggs were laid by Heliothis zea on trichomeless (near isogenic) lines than on trichomed ones.

### 2.3.3.2. Induced Resistance

The nature of soil fertility may affect the suitability of the host plant to insect development. Leuck (1972) found that when fall armyworm larvae were given a choice, the NP and NPK treated plants were preferred to those treated with to N, K, NK, PK, and P. Weight gains were lower of larvae reared on N, P, K, NK, and PK fertilized plants; but larvae reared on N and NK treated plants died before pupation. On the N treated plants, the larvae died after 23 days. Rapid development was observed on NPK, NP, and unfertilized plants. Adult emergence was significantly less on P,K, and PK treated foliage. The increased duration of post-embryonic development resulting from some fertilizer treatments has been suggested as a means of reducing the number of generations and increasing the chances of parasitism.

### 2.3.3.3. Intraspecific Resistance in Pearl Millet

Screening for resistance against the insect pests feeding on pearl millet has not been taken up on a large scale, although some work has been reported by Pradhan (1971), Jotwani (1978), Breniere (1980), and Sharma and Davies (1982), Sharma (1986), and Ndoye et al. (1986). Screening work has also been carried out under the All India Coordinated Millet Improvement Project, and some of the lines identified as resistant/promising/less susceptible are listed in Table 5.

## 2.3.4. CHEMICAL CONTROL

Insecticides are one of the most powerful tools available in pest management. When intelligently used, they are highly effective, rapid in action, adaptable to most agricultural situations and are flexible in meeting changing agronomic, ecological, and economic requirements. For some pest problems, the use of insecticides is the only acceptable solution. However, the use of insecticides can lead to adverse effects, such as insect resistance to insecticides, pest resurgence due to destruction of natural enemies, toxicity to non-target organisms, insecticide residues, and direct hazards to the user.

Very little emphasis has been placed on developing insecticide spray schedules to control millet pests. The main reason for this is that pest problems are less severe, cost/benefit ratios are low, and socio-economic conditions associated with the subsistence nature of millet production. Most of the work on chemical control has been confined to comparing the relative toxicities of insecticides to certain pests. Some of these data are summarized in the following pages.

### 2.3.4.1. Soil Insects

White grubs (*Holotrichia* spp) and false wireworms (*Gonocephalum* spp and *Arthrodes* sp) are the most important soil insects damaging millets. White grubs are the most injurious and difficult to control, although farm yard manure (FYM) mixed with BHC (10%) dust @100 kgha has been found to give effective control (AICMIP 1975). The FYM acts as an attractant to the larvae while BHC controls them. Phorate granules (@ 7.5 kg aiha) or BHC (10%) dust has also been recommended for white grub control by various workers (Kalra and Kulshreshtha 1961; Desai and Patel 1965; Patel and Patel 1953; Patel et al. 1967; Joshi et al. 1969; Rai et al., 1969; Yadva and Yadva 1973). Of these, phorate is a costly and highly toxic insecticide while higher doses of BHC may prove to be phytotoxic, especially to the germinating seedlings. Rangarajan (1966) did not observe any differences in the efficacy of BHC, DDT, chlordane, lindane, dieldrin, parathion, heptachlor, and aldrin in a trial conducted on finger millet. Some studies have also been conducted against the adults. Spraying the bush or tree hosts of the adults with fenitrothion, carbaryl, BHC and endosulfan has been suggested by some workers (Bindra and Singh 1971; Jotwani and Butani 1978). Sevidol (R) (Carbaryl:BHC:4:4) applied @ 20 kgha has been reported to be effective against *H. reynaudi* (Sachan and Pal 1976). Soil drenching or spreading aldrin soaked FYM has been found to suppress the damage by false wireworms, *Gonocephalum* spp at ICRISAT Center (Sharma and Davies 1982). Dieldrin (1.5%) or BHC (10%) dust have been reported to give effective control of *Arthrodes* sp (Rangarajan 1965). *S. minor*, which is a serious pest on pearl millet roots, can be suppressed with aldrin, chlordane, heptachlor or BHC (Nair 1975; Jotwani and Butani 1978).

### 2.3.4.2. Seedling Pests

Shoot flies and stem borers are the most important seedling pests. Seed treatment with carbofuran helps to reduce shoot fly damage (Anon. 1973 ab). However, seed treatment is effective only for two weeks. Soil application of phorate, disulfoton, aldicarb, and arprocarb @ 3 kg aiha have been found to give effective control (Singh and Jotwani 1973). Phorate may, however, affect seed germination (AICMIP 1974).

Talati and Upadhaya (1978) have recommended sprays of endosulfan (0.05%) and demeton-methyl (0.025%). Carbofuran (@ 1 kg ai/ha ) or quinalphos (@ 2 kg ai/ha ) give effective and economic control of shoot fly damage in Kodo millet (Raghuwanshi and Rawat 1985). On P. miliaceum, sprays of demeton-S-methyl (0.03%) and endosulfan (0.03%) were found to be effective for shoot fly control (Singh et al. 1983).

The use of insecticides has not been very successful against stem borers. However, repeated applications of endrin, carbaryl, BHC, and parathion have been shown to reduce the incidence of C. partellus and S. inferens (Nair 1975). Endrin has also been reported to give effective control of A. ignefusalis, B. fusca, and E. saccharina in Africa. To be effective, the insecticidal application should, however, coincide with the hatching of first instar larvae or before they enter the stem (Harris 1962).

2.3.4.3. Leaf Defoliators

Grashoppers and locusts quite often defoliate the crop severely. Dusting with BHC (10%) gave fairly good control of the grasshoppers C. sphenarioides, H. nigrorepletus, and O. simulans (Jotwani and Butani 1978). In laboratory tests, Verma et al. (1968) found dieldrin, aldrin, lindane, trichlorfon, malathion, parathion, telodrin, DDVP, and formothion to be more toxic than BHC to the adults of C. trachypterus.

Leaf feeding caterpillars form another important group of defoliators. A large number of insecticides have been tested against the oriental armyworm, M. separata (Sharma and Davies 1983). DDT, BHC, aldrin, phosphamidon, chlorpyriphos, malathion, parathion, trichlorfon, endosulfan, quinalphos, dichlorvos, and carbaryl have been reported to give effective control (Butani 1955; Hamblyn 1959; Purohit et al. 1971; Kalode et al. 1972; Gargav and Katiyar 1972; Singh and Mavi 1972; Hitchock 1974; Patel et al. 1979; Singh et al. 1980). For red hairy caterpillars (A. albistriga and A. moorei), sprays of isobenzan (0.05%) have been suggested (Patel et al. 1966). Insecticide applications are most effective against the early instar larvae. The black hairy caterpillar (E. lactinea) can be controlled by dusting BHC (Jotwani and Butani 1978). Methyl-parathion and hinosan have been reported to be effective against the larvae of the noctuid caterpillar P. signata (Rangarajan et al. 1974).

The grey weevil (Myllocerus sp) is another important leaf feeder. Shinde et al. (1970) reported that mevinphos, dicrotophos, and fenitrothion were more effective against it than DDT. In laboratory tests, Verma et al. (1969) found ethyl-parathion, malathion, endrin, mevinphos, telodrin, and formothion to be more toxic than DDT.

2.3.4.4. Sucking Insects

A number of sucking pests feed on millets. The rusty plum aphid (H. setariae) feeding on finger millet can be controlled with endosulfan

(Saroja et al. 1972) or (2-chloro-ethyl) trimethyl ammonium chloride (Dasan and Kolandaswamy 1974). The maize aphid (R. maidis) can be controlled with phosphamidan, dimethoate, diazinon or demeton-methyl (Jotwani and Butani 1978). The greenbug, S. graminum was reported to be controlled by parathion (Dahms 1951) or disulfoton (Daniels 1961). Wood (1971) also found that most of the organophosphates gave good control of aphids; whereas Peters et al. (1975) reported that the greenbug could not be controlled even with very high doses of some organophosphates, indicating the development of resistance. Carbofuran has been found to reduce the populations of the jassid, C. bipunctella bipunctella, and this treatment also led to early flowering and increased plant height (AICMIP 1972). Jotwani and Bhutani (1978) recommended carbaryl, dimethoate or BHC for the control of shootbug, P. maidis, and malathion and fenitrothion for the sugarcane leaf hopper, P. perpusilla. Fenitrothion and monocrotophos have been found to be effective and persistent against the milkweed bug, S. pandurus (Sandhu et al. 1974a). The stink bugs (N. viridula, D. indicus and B. cruciferarum) can be controlled with malathion, dichlorvos or lindane. Sandhu et al. (1974b) have reported a number of insecticides to be effective against B. cruciferarum. The thrips, A. sudanensis and H. traegardhi can be controlled with dimethoate, demeton-methyl or phosphamidan. Sulphur dusting is effective against the spider mite, O. indicus (Nair 1975).

2.3.4.5. Earhead Pests

Vercambre (1977 and 1978) suggested 1 - 2 applications of endosulfan for the control of earhead borers, Masalia spp and Raghuva spp. The first treatment should be given at the head elongation stage and the second 5-7 days later. Other insecticides such as chlordimeform, dimethoate + deltamethrin, trichlorfon, and diflubenzuron (dimilin) have also been reported to be effective for the control of head caterpillars in Africa (Ndoye et al. 1986). The earhead worms, C. gnidiella and E. silicula can be controlled by applying monocrotophos or endosulfan (Srivastava and Singh 1973).

Severe infestations of blister beetles (M. pustulata, C. ruficollis, and P. rouxi) can be controlled with spraying carbaryl and endosulfan. Yadava et al. (1973) reported that dusting with BHC gave effective control of the chafer beetle, R. laeviceps. Dust formulations of parathion, fenitrothion, lindane, carbaryl, and BHC gave over 90% kill of the beetles (Mishra et al. 1979). Fentin has also been found to afford protection against Rhinyptia spp (Verma 1979). Carbaryl and BHC sprays or dusts give effective control of the head bug species, C. angustatus and L. acuta (Nayar et al. 1976; David and Kumraswamy 1975). Blossom thrips (T. florum, H. ganglbaueri, and H. gowdeyi) can be controlled by spraying flowering heads with lindane, malathion or carbaryl (Jotwani and Butani 1978). Anathakrishnan (1971) has suggested the use of dimethoate, phosphomidan, thiometon, and endosulfan for the control of thrips. Santharam et al. (1976) recommended methyl-parathion + DDT for the control of pearl millet midge, G. penniseti. Phosalone has also been reported to be effective for the control of pearl millet midge (Ndoye et al. 1986).

# 3. STORED GRAIN PESTS

Many insect and mite species attack the stored grain. The damage leads to both quantitative and qualitative losses. The grain stores provide an un-disturbed shelter, favorable environment and abundant food supply. All pests of stored grains have a remarkably high rate of multiplication, destroy large quantities of grain in a short span of time, and contaminate the rest with excreta and undesirable odours (Atwal 1976). Fourteen species have been reported to damage millets in different parts of the world (Table 6). However, it is most likely that the insects damaging other cereals and their products are also injurious to millets. Various aspects of the pest problems in storage have been discussed by Mehta and Verma (1968), Pradhan (1969), Pringle (1964, 1976), Rachie and Majmudar (1980), and Freeman (1980).

## 3.1. ECONOMIC IMPORTANCE

Storage losses can be exceptionally high, and have been estimated to vary from 10 to 60% (Rachie and Majmudar 1980).

## 3.2. BIOLOGY AND BEHAVIOUR

### 3.2.1. Lesser Grain Borer (*Rhizopertha dominica*)

Lesser grain borer, *Rhizopertha dominica* adults have a polished dark brown appearance, with the head turned down below the thorax. Adults and larvae destroy large amounts of grain producing considerable frass and flour. Their damage leads to the development of heat pockets in the granary (Pringle 1976). Each female lays upto 250 eggs. Early stage larvae (upto 3rd instar) are free living outside the grain. Thereafter, they enter the grain where they complete their development. The life cycle is completed in about 25 days. This species can tolerate a lower moisture content of more than 7 percent.

### 3.2.2. Khapra Beetle (*Trogoderma granarium*)

The khapra beetle, *Trogoderma granarium* is brownish black and oval in shape. The larvae are covered with long brown hairs, and have yellow intersegmental rings. The grubs feed on the grain. This insect can damage grain dried to a moisture content of 2%. The grubs can live without food for years, and can resist adverse environmental conditions. A female lays upto 120 eggs in 10-15 days, and the life cycle is completed in about 4 weeks under favourable conditions (Pradhan 1969).

### 3.2.3. Rusty Flour Beetle (*Cryptolestes ferrugineus*)

The rusty flour beetle, *Cryptolestes ferrugineus* is a cosmopolitan insect and is tolerant to a wide range of temperatures and humidities. Larvae feed inside the grains. Infestation is favoured by high humidity. A female can lay upto 200 eggs, and lives for 6-9 months. There are four larval instars. Life cycle is completed in about three weeks (Pringle 1976).

### 3.2.4. Rice Weevil (*Sitophilus oryzae*)

The rice weevil, Sitophilus oryzae is the most destructive pest of stored grain in the world. Both the adults and the grubs damage the grain. The adult is an elongate, reddish brown beetle, about 3 mm in length, and lives for 4-5 months. The eggs are laid on the grain in a cavity made by the female with the help of powerful jaws. A female lays 300-400 eggs. The grubs bore into the grain and complete their life cycle inside the grain in about 3-4 weeks. Winter may be passed in either the adult or larval stage. It cannot breed in grain with a moisture content less than 9.5% (Pradhan 1969).

3.2.5. Maize Weevil (Sitophilus zeamais)

The maize weevil, Sitophilus zeamais adults are slightly larger than the rice weevil. Females can fly readily and are known to attack standing crops, particularly maize cobs, already damaged by other insects and birds. Its biology is similar to S. oryzae.

3.2.6. Merchant Beetle (Oryzaephilus mercator)

The merchant beetle, Oryzaephilus mercator is common in tropical climates. It is less tolerant to lower temperatures and humidity.

3.2.7. Saw-toothed Grain Beetle (Oryzaephilus surinamensis)

The saw toothed grain beetle, Oryzaephilus surinamensis is a small brown beetle, with serrated lateral edges to the thorax. A female may lay upto 375 eggs. The life cycle is completed in about 3 weeks. At lower temperatures, the adults can survive for more than a year.

3.2.8. Rust-red Flour Beetle (Tribolium castaneum)

The rust-red flour beetle, Tribolium castaneum is a small reddish brown beetle which generally prefers to feed on damaged grain. Both the adults and the grubs damage the cracked grain. A female lays upto 10 eggs/day and oviposition continues for several months. A female may lay upto 1000 eggs. Under favourable conditions, the life cycle is completed in 3-4 weeks (Pringle 1976).

3.2.9. Confused Flour Beetle (Tribolium confusum)

The confused flour beetle, Tribolium confusum is common in temperate climates. Cannibalism is common under crowded conditions. Under favorable conditions, this pest competes successfully with other primary pests (Pringle, 1976).

3.2.10. Angomois Grain Moth (Sitotroga cereallela)

The Angomois grain moth, Sitotroga cereallela is cosmopolitan, and the damage is confined to the upper layers of the grain. The damaged grain gives an unpleasant smell. The adult is a small yellowish brown moth with prominent fringes along the wing margins. A female lays upto 400 eggs. The eggs are small and white when freshly laid. The egg incubation period is 4-5 days in summer. The larvae enter the grain and complete their development inside the grain. The larval period lasts for about 3 weeks, and the life cycle is completed in 4-5 weeks. It overwinters as a larva. It is unable to breed in grains with low moisture content, so that most of the damage occurs during the rainy season when the humidity is high (Pradhan 1969).

3.2.11. Rice Moth (Corcyra cephalonica)

The rice moth, Corcyra cephalonica is a pale buff-brown moth. The larvae produce a dense webbing, which tends to bind the grain into lumps. The eggs are laid singly or in groups of 3-5 on the grains. A female lays upto 150 eggs in 2-4 days. The eggs hatch in 4-7 days and the larvae complete development in 21-41 days. The pupal period lasts for 9-14 days. It overwinters in the larval stage and there are several generations in a year (Atwal 1976).

3.2.12. Almond Moth (Ephestia cautella)

The almond moth, Ephestia cautella is a small grey moth, which can develop rapidly in stores during the rainy season. The damage is usually confined to the upper 50 cm layer of grain. The germ of the grain is damaged preferentially. A female lays about 250 eggs and the life cycle is completed in 4-6 weeks. Pupation occurs inside the grains. Moths are attracted to water and moist surfaces and reproduction is less under dry conditions. The larvae, which hibernate during the winter months may be collected by placing an empty gunny bag on a heap of grain (Atwal 1976).

3.2.13. Indian Meal Moth (Plodia interpunctella)

The Indian meal moth, Plodia interpunctella is red-brown with the underside creamy white. Its larvae cover the grain surface with a webbing of silken threads. Damage is normally confined to the germ. A female lays upto 200 eggs and the life cycle is completed in 4-6 weeks (Pringle 1976).

3.2.14. Mite (Acarus siro)

The grain mite, Acarus siro is the most common grain mite. The mites are whitish to pale yellow, and breed very rapidly under damp conditions. Damage is mostly of the seed germ, and the grain acquires a peculiar taste which persists in the final product (Pringle 1976).

## 3.3. CONTROL MEASURES

The extent of grain damage in storage largely depends upon the moisture content of the grain, availability of oxygen, and the development of a temperature gradient within the stored grain (Pradhan 1969). To ensure grain safety from insects and other organisms, the above factors should be suitably manipulated through the proper construction of buildings and appropriate storage practices. In some cases physical and/or chemical control of infestations may become necessary. Insect damage may be minimised through: 1) appropriate storage facilities, ii) storage hygiene, iii) control of moisture content of grain, iv) physical methods, v) chemical methods, vi) biological methods, and vii) grain resistance to insect damage (Pringle 1976).

### 3.3.1. STORAGE FACILITIES

The storage facility should be airtight and free of cracks, crevices and dampness. Storage structures can be made of steel or concrete. For safe storage of small quantities of grains, the Pusa bin has been found be very useful (Pradhan 1969). The storage facility should be properly constructed from the point of view of warehouse management and the prevention and control of insects.

### 3.3.2. STORAGE HYGIENE

The storage facility should be completely clean, and regularily inspected. Spillage of grain on the floor should be minimum, and cleaned regularily.

### 3.3.3. CONTROL OF MOISTURE CONTENT

Grains with a moisture content lower than 10% are relatively less damaged. Maintenance of adequate free space between sacks and allowing natural aeration on dry days helps to reduce the humidity.

### 3.3.4. PHYSICAL METHODS

Turning and disturbance, screening, aeration, use of heat and cold, impact through centrifugal force, mixing of inert dusts, use of insect proof and polyethylene lined sacks, ultrasonic sounds (20,000 Hz and above), radio waves, light and X and r rays, and infra red radiation have been used for insect control in storage with varying degrees of success (Pringle 1976).

### 3.3.4. CHEMICAL METHODS

Synthetic insecticides are used for insect control as a last resort. The choice of insecticide depends upon the mode of application and residues on the grain. Insecticides can be used for protective tretment of storage structures, warehouses, or the surfaces of storage bags. Jute or cloth bags may be treated with lindane, DDVP, malathion or pyrethrins (Pringle 1976). Insecticides such as malathion are also mixed with grains directly. However, direct mixing is prohibitd in many countries because of the contamination of grain used as food by insecticide residues.

Fumigants can be successfully used in airtight storage structures. The commonly used fumigants are carbon tetrachloride with ethylene dichloride (25:75), ethylene dibromide, methyl bromide, ethylene dichloride, ethylene oxide, hydrogen cyanide, and phosphine. Further information on the use of fumigants on stored grains is given by Pringle (1976).

### 3.3.5. BIOLOGICAL CONTROL

Many organisms are the natural parasites of the immature stages of beetles and moths. Important natural enemies include protozoa (<u>Schizogregarinos</u>, <u>Cociidis</u>, and <u>Microsporidia</u>), bacteria (<u>Bacillus</u>

<u>thuringiensis</u> Berliner), nuclear polyhedrosis and granulosus viruses etc. Biological control measures have not so far been used successfully and more work is required on their development as economic alternatives.

3.3.6. GRAIN RESISTANCE

Certain varieties are less damaged than others. A systematic screening of different cultivars may be carried out to identify cultivars that are damaged less by the storage insects.

# 4. GRAIN EATING BIRDS

Grain eating birds are the most serious pests of millets, both in India and Africa. However, crop losses due to birds are much more serious in sub-Sahelian Africa than in the Indian Sub-continent. Among the grain eating birds, the small passerine species present the greatest threat in most of the millet producing countries. Most of the pearl millet grown in the semi-arid Sahel is within the range of the most notorious bird pest - the Red-billed Quelea (*Quelea quelea*). It is the most serious and numerous avian pest in the world. Other important grain eating birds include various species of weavers (*Ploceus* spp), sparrows (*Passer* spp), parakeets (*Psitacula* spp), pigeons (*Columba* spp), crows (*Corvus* spp), and doves (*Streptopelia* spp). A large number of bird species have been reported to cause substantial damage to millets and are listed in Table 7.

## 4.1. ECONOMIC IMPORTANCE

The impact of birds on agricultural production has led to the formation of several regional and international bird control organisations in Africa (Bruggers and Jaeger 1982). Although the impact of bird pests on grain production is generally recognized, until very recently, only a little quantitative information on crop losses was available. In Senegal, annual cereal losses due to birds were valued at $4-5 million, with sorghum and millet suffering more than 78% of these losses (Bruggers and Ruelle 1981). In the Sudan, bird damage has been estimated to cause a loss of $6.3 million annually (Anon. 1981b). Birds are also very serious pests of millets in India (Jain and Ishwar Prakash 1974; Bhatnagar 1976a and b; Fitzawater and Prakash 1974; Mehrotra and Bhatnagar 1979; Agarwal and Bhatnagar 1982). In India, nearly 10% of the grain is estimated to be destroyed by birds (Jain and Ishwar Prakash 1974). Pigeons have been found to destroy 10-100% of pearl millet at sowing, while sparrows account for upto 29% of grain loss in Punjab (Toor 1982). The extent of bird damage in pearl millet is so high, that the farmers prefer to cultivate them for fodder purposes only (Jotwani et al. 1969a). At Delhi, some pearl millet varieties were damaged upto 90% (Bhatnagar et al. 1974). Birds damage 10-20% of the grain between the time of crop harvest to granary (Sharma 1982). The extent of losses have been estimated to range between Rs.600 to 1800 per hectare (Bhatnagar et al. 1982b). Yield loss estimates from other millet growing countries are not available. Even a conservative estimate of 5% grain loss due to bird damage of a total of 44 million metric tons of millets produced annually (Rachie and Majumdar 1980), would exceed 2.2 million metric tons, valued at $272.8 million.

## 4.2. BIOLOGY AND BEHAVIOUR

The biology, movements and crop losses have been more intensively studied for the red billed quelea than for any other bird species. General information is also available on weavers, sparrows, pigeons and the doves. For more details, the readers should consult more detailed works on birds (Schmutterer 1969; Mehrotra and Bhatnagar; 1979; Agarwal and Bhatnagar 1982; Salim Ali and Laeeq Fute Hally 1982; Manikowski, 1984).

4.2.1. Blue Rock Pigeon (Columba livia)

The blue rock pigeon is slaty-grey with a glistening metallic green sheen on the neck and the upper breast, two dark bars on the wings and a broader one across the end of the tail. It is common in India and may be found associated with old wells, hill forts, and ledges and fissures of rocks. They fly back and forth to newly sown or harvested cereal fields. The nest is a sparce bed of twigs and straw, and two unmarked white eggs comprise a brood. This bird is equally adapted to wild, rural, and urban habitats.

4.2.2. Red Bishop (Euplectus orix)

The red bishop is widely distributed in the Sahelian and Sudanian regions. The red bishop is a striking bird because of the bright colors of the male during the breeding season. The crown, face,lower breast, and belly are black. The neck, throat, breast, rump, and the tail are brown. It constructs a globular grass nest among low bushes or tall grasses. It feeds on grass and cereal seeds, and the damage may be considerable locally. It forms medium sized flocks in areas of cultivated land.

4.2.3. Blue-tailed Starling (Lamprotornis chalybaeus)

The blue-tailed starling is a metallic glossy-green colored with a bronze colored belly and rump and a bluish-green tail. It is widely distributed in Africa. Small grain cereals may be severely damaged locally. It makes use of the abandoned nests of other birds in trees for breeding.

4.2.4. House Sparrow (Passer domesticus)

The house sparrow is almost cosmopolitan. Large flocks of birds may congregate and feed in and around cultivated areas on insects, ripening grain, and seed found on the ground. They destroy large numbers of insect-pests, particularly when they feed the young. Large congregations of the sparrows roost on the favourite leafy trees or houses. Its nest is a large collection of straw and rubbish, stuffed into a hole in a wall or ceiling. It lays 3-5 pale greenish-white eggs marked with various shades of brown.

4.2.5. Grey Sparrow (Passer griseus)

The grey sparrow is a minor pest of cereals in Africa. The head is grey-brown, the back brown with a rufous wash. The wings and tail are brown. The birds live in towns, villages and in the bushland, and cause damage to small grain cereals grown nearby. Nests are built in tree trunks during the rainy season.

4.2.6. Golden Sparrow (Passer luteus)

The golden sparrow is widely distributed throughout the Arid Semi-desert-Sahel. It congregates near water during the dry season. Each pair makes 2-3 nests of small branches in a tree or thorny bushes in the desert.

4.2.7. Village Weaver (Ploceus cucullatus)

The village weaver is one of the most serious pests throughout tropical Africa. It lives near human inhabitations. The under parts of the breeding male are golden yellow, except for a black throat. The hind neck is deep cinnamon yellow. The birds gather in small to medium sized flocks and cause substantial damage to cereals during breeding time. The bag shaped nest is built of strongly woven grass and is firmly fixed on the top branches of trees including palms.

4.2.8. Little Weaver (Ploceus luteus)

The little weaver is common in Africa. In the breeding male, the front half of the crown, cheeks, throat, and the bib are black. The posterior half of the crown, sides of the neck, breast, and belly are yellow. The wings and tail are dusky with yellowish edges. It mostly damages grain during the milky stage of development.

4.2.9. Baya Weaver (Ploceus philippinus)

The baya weaver is widely distributed in India. It is known for its remarkable woven retort-shaped nests hanging from trees in the neighbourhood of the cultivated fields. During the non-breeding season, the male and female look like house sparrows and are indistinguishable from each other. During the breeding season, the male assumes a yellow plumage and builds a number of successive nests in the same colony, which are taken over by females one by one when half ready, and if so accepted. This way, each cock may have 4-5 families, all more or less at the same time. The birds form large flocks in the open country around cultivated areas moving locally, and the movements largely depend on monsoons and cropping pattern.

4.2.10. Rose-ringed Parakeet (Psitacula krameri)

The rose ringed parakeet is widespread in India and Sahelian and Sudanian regions. It is grass-green colored with a typically short, stout, deeply hooked red bill, and a black and rose-pink collar. It forms large flocks and may congregate in the cultivated areas where food is abundant. Large flocks can cause considerable damage. The nature of feeding is such that the parakeets tend to waste far more than they actually consume. Parakeets have common roosts in groves of trees and lay 4-6 round whitish eggs.

4.2.11. Red-billed Quelea (Quelea quelea)

The red-billed quelea is the most studied and serious pest of small grains in the African continent. In the breeding season, the male is yellowish white, rarely with a pink crown. The sides of the head, and the throat are black, the wings and the tail yellow. The beak is rose-red and the legs pink. It is very gregarious in all seasons, and prefers open territory in the vicinity of rivers and other suitable water. Its great flight activity enables it to rapidly cover long distances. Very large flocks of birds feed on cereals especially during the breeding season and often in fields far away from the nesting sites. The whole crop may be destroyed within a few days or even in a few hours. A bird consumes 3-4 grams of grain everyday, but more is wasted when it falls to the ground. Insects are also consumed at the beginning of the rainy season and during nest building. Cereal production within the main nesting areas and along migration routes has been an important factor contributing to its increased importance over recent years. Breeding takes place in the Savanhahs, and the nesting sites often occupy many square kilometers. A bag like nest is constructed by the male from woven grass and fixed firmly to the branches of thick bushes or in tall grasses. Several hundred nests may sometimes be found in one bush. At the end of the rainy season (August-October), 2-3 blue colored eggs are laid. The fledglings are fed mainly with insects during early days, and later on, the diet is entirely of plant origin. The young birds leave the nests 10-12 days after hatching from the eggs, and remain near the breeding site untill they fly away. There are several broods during migrations, which follow the rains and maturing crops.

### 4.2.12. Mourning Dove (Streptopelia decipiens decipiens)

The mourning dove is widely distributed in the Sahelian Sudanian regions. The head is grey, with a black half collar, upper portion brown, and the end of tail white. The underside is pale lilac, the eyes yellow, the feet grey-red, and the bill black. It often does more damage along field margins and moves about in small flocks.

### 4.2.13. Turtle Dove (Streptopelia turtur turtur)

The turtle dove is distributed throughout Sudanian region and is normally seen in the grain fields only at harvest time. The sexes are similar in color. Black and white patches on the sides of the neck enable the species to be easily identified.

### 4.2.14. Pink-headed Dove (Streptopelia decaocto roseogrisea)

The pink headed dove is smaller than the mourning dove and is commonly seen in grain fields in the Sudan. The head is a pale pinkish grey. The neck shows a broad half collar of black, bordered with white.

### 4.2.15. Laughing Dove (Streptopelia senegalensis senegalensis)

Laughing dove is common in the Sahelian and Sudanian regions, and has pink head, throat, and breast with blue-grey shoulders and wing tips. It constructs a flat nest of twigs in trees. Small flocks visit the grain fields in the vicinity of settlements.

## 4.3. CONTROL MEASURES

Efforts to reduce grain losses due to bird damage seem to be far from satisfactory. Many traditional and newly developed techniques are in use to combat the menace of grain eating birds. Extensive population reduction techniques are estimated to have killed nearly 109 billion birds annually (Ward 1979). However, this does not seem to have reduced the damage caused by the red billed quelea to tolerable limits (Funmilayo and Akande 1979), except in the Senegal river valley (Bruggers and Ruelle 1981). The various techniques employed for bird control and their usefulness have been discussed by Schaffer (1978), Ndiaye (1979), Agarwal and Bhatnagar (1982), Bruggers and Jaeger (1982), Ruelle and Bruggers (1982), and Bruggers et al. (1984). The various bird control methods used in the traditional farming and those being newly developed are briefly described in the following pages.

### 4.3.1. TRADITIONAL METHODS

Among the traditional methods, bird scaring is an important component in subsistence farming (Dogget 1957). Most of the farm families protect their millet crop with the same traditional methods used since the beginning of cultivation. The most common methods include; i) frightening the birds by shouting, ii) beating empty tin cans, iii) throwing stones or mud pellets at the bird flocks, iv) covering the crop heads with leaves or cloth, v) hanging dead birds (such as a crow) over the crop canopy, vi) cutting or burning the nest bearing trees, and vii) using acetylene gun or other bird scaring devices. However, these methods are only useful on small areas which can be easily managed by the farm family and in actual practice, it only tends to distribute the damage more uniformly. As agricultural practices are upgraded and farm size is increased, these methods become impractical. Moreover traditional methods are effective only at moderate levels of damage. Under heavy levels of bird attack such as those of quelea, these control operations cease to be effective. Bird control constitutes 15-80% of the production costs on government farms (Bruggers 1980).

### 4.3.2. PHYSICAL BARRIERS

Physical barriers such as fish nets or nylon nets are also used to protect the ripening cereals from the birds. Nets are now being more regularly used on research farms. These are particularly useful for isolation blocks and off-season nurseries. The high cost of the nets limits their use in commercial and traditional farming. However, the cost of using nylon nets compares favourably with that of hiring bird scarers for the entire maturation period of the crops (Bruggers and Jaeger 1982).

### 4.3.3. PLANT PHENOLOGY

Long or short duration varieties can be planted depending upon the length of time the grain eating birds are present in an area. The varieties planted should mature during a period of low bird activity. However, this is complicated by the length of the crop growing period and by inconsistencies in the amount of rainfall received. The extent of damage varies with maturity, plant height, and availability of the grains at the tip of the earhead. Compact earheads with small grains were less damaged as also the earheads with awns (Bhatnagar et al. 1982a). Plant characters such as bristles and anther covering of the grain have also been reported to be associated with resistance to birds (Beri et al. 1969). However, plant resistance is a relative term and it is highly improbable to develop varieties which will not be eaten by birds when no alternatives are available. Bhatnagar et al. (1974) and Singh (1980) have suggested the cultivation of awned varieties. Cultivars MBH 110, MH 88, MH 38 and PHB 14 have been found to be less damaged by birds (Kishore and Bhatnagar 1982; Kishore and Gupta 1982).

4.3.4. BIOACOUSTICS

Distress alarm or warning calls have also been exploited for bird control. These calls can be recorded and replayed at regular intervals. These calls can be very effective in scaring some bird species such as parakeets. Some bird species do not produce distress calls and this method cannot be employed against them.

4.3.4. CHEMICAL CONTROL

Use of synthetic repellents is one method of reducing damage by grain eating birds, and it is receiving considerable attention from research workers throughout the world. Metzer and Royal (1961) reported thiram to be an effective bird repellent. Malathion also acts as a feeding deterrent to birds (Mehrotra et al. 1967). Tetramethyl thirum disulphide has been found to be effective in reducing bird damage (Bhatnagar et al. 1982b). Methiocarb has given encouraging results as a bird repellant and is effective against the red billed quelea at a level of 0.015% (Shumake et al. 1976), and protects pearl millet effectively (Bruggers and Jaeger 1982). It can be safely applied to the ripening grain at repellent levels without harmful residues (Gras et al. 1981). The techniques of using methiocarb are also changing from those of covering the whole fields to spraying only the field edges or the spots in the field that are being damaged. Other compounds showing bird repellent properties are anthraquinone, napthalene, DRC 3324, and 4 aminopyridine (Toor 1982).

One of the common methods of bird control includes the spreading of grains treated with insecticides (methyl parathion, monocrotophos and endrin) in spots easily accessible to the birds or spraying the roosting sites with highly toxic insecticides such as parathion or fenthion. Insecticides such as carbaryl and methiocarb have also been reported to reduce bird damage by controlling the insect larvae that are attractive to the birds (Woronecki and Dolbeer 1980). The present situation on the registration and usefulness of bird damage control chemicals has been discussed by Schaffer (1979). Bird stupefying chemicals such as Avitrol 100 (R) (4-nitropyridine N-oxide) and Avitrol 200 (R)(4-aminopyridine) are effective against sparrows and black birds, while alphachloralose has been used against pigeons, sparrows and starlings. The stupefied birds can be collected and killed (Toor 1982)

# 5. RATS AND MICE

Rodents constitute a large group of mammals, and are small to medium sized animals. Many rodent species are very fertile and breed the whole year round. Serious outbreaks are often observed periodically that result in heavy damage to various crops and stored products. Many species have been reported to damage cereals (including millets) in various parts of the world (Table 8). Cricetids, Gerbillus nanus indus, Meriones hurrianae, and Tatera indica are important in South Asia, while Gerbillus pyramidum, Tatera quineae, and Tatera kempi are common in Senegal(West Africa). Among the murids; Bandicoota indica, Mus musculus, and Nesokia indica are distributed in South Asia, while Arvicanthus niloticus, Mastomys natalensis, and Mus minutoides are more common in Africa. Rattus norvegicus and Rattus rattus are found both in Asia and Africa.

## 5.1. ECONOMIC IMPORTANCE

Rodents cause considerable damage both in the field and stores. Exact yield loss estimates due to rodents in millets are not available. In a survey carried out through a questionaire by Hopf et al. (1976), grain losses of up to 20% have been reported. In addition to grain losses, rats and mice also spread a number diseases such as plague, murine typhus, leptospirosis, rat-bite fever, trichinosis, rickettsial pox, and food poisoning.

## 5.2. BIOLOGY AND BEHAVIOUR

### 5.2.1. Egyptian Gerbil (Gerbillus pyramidum)

The Egyptian gerbil, Gerbillus pyramidum is nocturnal and crepuscular. Its burrows are generally among dense growth of bushes. The gerbils usually stay within a few yards of their burrows and when chased, they soon disappear down a hole. Foot prints and tail drags are especially noticeable in the morning around burrows. Its body weight is 33-51 g. Males are heavier than females. They breed throughout the year except at the end of the dry season. They tend to remain in colonies. Each female produces 2-7 young per litter (Happold 1976).

### 5.2.2. Indian Gerbil (Tatera indica)

The Indian gerbil, Tatera indica is brownish red with a white belly, and is 11-20 cm long, with a tail longer than the body. It is a very sensitive and fast moving rat. A female produces 5-10 young per litter. It makes burrows in sandy areas, and the burrow opening is located under the cover of a thorny bush or other vegetation. The burrows are deeper and short in length. Generally, there is one rat in a burrow (Atwal 1976).

### 5.2.3. Nile Rat (Arvicanthus niloticus)

The Nile rat, Arvicanthus niloticus is 15-18 cm long with 10-13 cm long tail. Hair on the dorsal side are buff to black colored, while underside hair are greyish-white. It breeds all the year round whenever the food supply is sufficient. Five or more generations may occur per year. Most breeding takes place during the cropping period, when they store large quantities of food in the burrows (Schmutterer 1969).

5.2.4. Multimammate Rat (Mastomys natalensis)

The multimammate rat, Mastomys natalensis is about 12-14 cm long, and the tail is 10 to 12 cm. Hair yellowish to dark brown. It dwells in or near human settlements. Its binomics is similar to that of Nile rat (Schmutterer 1969).

5.2.5. House Mouse (Mus musculus)

The house mouse, Mus musculus is 7-10 cm long with a tail 7-8 cm long. The eyes and ears are small, and the tail is scantily haired. The back is uniformly brown and under parts pale brown to whitish. It climbs readily. It does most damage in stores and around human inhabitations. Each female delivers 5 to 6 young per litter, which begin to move in about 21 days. It is short lived and most individuals do not live for more than a year. At times, the population increases very rapidly (Atwal 1976).

5.2.6. Indian Field Mouse (Mus booduga)

The Indian field mouse, Mus booduga is found both in dry and wet lands. The Back is brown and the belly a dull grey. It makes small burrows without branches, and lives in pairs. A female produces 6-13 young per litter (Atwal 1976).

5.2.7. Norway Rat (Rattus norvegicus)

The Norway rat, Rattus norvegicus is about 40 cm in length including the tail. The nose is blunt and ears of moderate size. The tail is scaly, naked, blunt ended, and shorter than the body. The hair is generally brown, interspersed with black, and underparts are yellowish-white. It normally stays at ground level. Tunnels are 5 to 7.5 cm in diameter, with more than one opening. A female produces 8-9 young per litter. It is large in size and bold in nature, and has replaced the black rat in many places (Mehta and Verma 1968).

5.2.8. Common Rat (Rattus rattus)

The common rat, Rattus rattus has a sharp slender nose, large ears, and the tail is longer than the rest of the body. The back and sides are black. The young ones move about after 21 days. It moves with tail raised from the ground. It normally prefers darkness. It is most active upto 18 months. It is color blind and is dazzled by light, and has an acute sense of smell, touch, hearing, and taste (Mehta and Verma 1968).

## 5.3. CONTROL MEASURES

Various aspects of rodent control have been discussed by Chitty and Southern (1954), Deoras (1964), Mehta and Verma (1968), Davies (1970), and Prakash and Gosh (1975).

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## 5.3. CONTROL MEASURES

Various aspects of rodent control have been discussed by Chitty and Southern (1954), Deoras (1964), Mehta and Verma (1968), Davies (1970), and Prakash and Gosh (1975).

The presence of rats and mice can be detected by their damage, sounds, runways, droppings, holes, smears, nests, urine stains, and actual sighting.

Principal methods of rat control include: 1) exclusion, ii) traps, iii) poison baiting, iv) fumigation, and v) others.

5.3.1. EXCLUSION

Openings more than one centimeter in width should not be left in stores. The floor and exterior of walls should be made of concrete. Screens may be provided around all openings. Doors and windows should be tight fitting. The surroundings should be kept clean.

5.3.2. TRAPS

Trapping is a preferred method of rat and mice control. Many types of traps are in use in different parts of the world. The most popular traps are wooden/steel breakback or guillotine traps, steel jaw traps, cage traps, and automatic traps. It is important to keep traps in good working condition in places generally frequented by rats and mice.

5.3.3. POISONED BAITS

Control through poisoned baits is the routine operation in stores and fields. Red squill, zinc phosphide, antu, warfarin, arsenic, barium carbonate, phosphorus, strychnine, and insecticides (endosulfan, endrin, malathion, parathion, etc.) are generally used for rodent control. Cereal grains, bread, and flour pellets are generally used as a carrier. Addition of vegetable oils and molasses increases the attractiveness of the baits. Pre-baiting with unpoisoned baits for 2-3 days in areas frequently visited by the rats may be done to remove the fear and suspicion to new objects, followed by poisoned baits for 3-4 days.

5.3.4. FUMIGATION

Many rats and mice hide in burrows and can be killed by poisonous gases. Calcium cyanide, sulfur dioxide, methyl bromide, carbon monoxide, aluminium phosphide etc. are generally used to fumigate the burrows of rats and mice. Redenticide or some insecticide dusts can also be applied into the burrows.

5.3.5. OTHERS

Destruction, flooding, and blocking of the burrows can also be effective in rat control. Rat populations are also controlled by cats, dogs, owls, eagles, and snakes.

## 6. STATE OF THE ART AND THE FUTURE NEEDS

Millet entomology is still in an exploratory stage with major emphasis on identifying the pest fauna associated with these crops. To date, 497 pests have been reported to feed on millets (Tables 2,6,7, and 8) in various parts of the world, and there may be many more, as yet un-accounted. Of these, 401 insect and mite species damage the crops under field conditions, 16 in storage, and 55 species of birds and 25 species of rats and mice result in substantial crop losses either in the field and storage or both. The insects feeding on seedlings and the earhead are particularly important. As the plant is most vulnerable to pests during the seedling stage, white grubs Holotrichia spp, shoot flies (Atheriogna spp), and stem borers (A. ignefusalis, C. partellus and Sesamia spp) are probably the most destructive pests. Although a large number (206) of insect species feed on the leaves, only a few (such as M. separata, Myllocerus spp, S. graminum, P. maidis, R. maidis, and various species of grasshoppers) occasionally cause serious damage. Insects feeding on the earheads directly compete with man for grain and can substantially reduce the grain yield. Of the 91 insect species feeding on the earhead; millet midge (G. penniseti), head caterpillars (Heliothis spp, Raghuva albipunctella , Eublema spp, and Cryptoblabes spp), head bugs (various species), and thrips are the most important.

A logical follow up of present knowledge of the important insect species damaging millets is to conduct pest surveys in the principal millet growing areas to examine the incidence pattern, seasonal abundance, severity of damage, and the extent of crop loss caused by important pests. Much of the experience gained on the pest problems on these crops has been obtained on research stations which are not necessarily comparable to the farmers' fields. There is a need to know more about the distribution and the extent of losses caused by important pest species and to identify priorities for research relevant to farmers' fields.

A considerable amount of information exists on the biology of a few pests. Although, in many cases, these studies relate to them as pests of other important crops. It is also necessary to study their biology and population dynamics on millets. While populations of some species may be monitored with light and other traps, and by direct counting, appropriate trapping and sampling techniques have still to be worked out for others.

At present, pest control schedules on millets are poorly developed, and little practiced or necessary. However, as yields increase and stabilize, pest control will become increasingly necessary and economically viable. Also pest situation may change considerably under the improved or changed crop husbandry practices and with the introduction of high yielding cultivars.

Certain cultural operations, such as timely planting and harvesting, deep ploughing before and after the cropping season, using mixed crop combinations, and field sanitation, have been used to reduce damage caused by some insect species. However, emphasis should be placed on making use of such cultural practices as a means of reducing pest damage in subsistence farming systems of millet producing areas. In fact, many of these practices are currently in widespread use. However, there is need to collect more data on the effectiveness of such operations and to educate the farmers in making optimal use of them. Natural enemies are an integral component of agro-ecosystems. However, the scope for success using a classical biological control against millet pests is limited largely because of the short duration of the cropping period and unfavourable crop environment. Attention needs to be focussed on the identification, conservation and encouragement of existing biological control agents. Special attention should be paid for using crop cultivars and mixed crop combinations that are relatively more hospitable to the natural enemies than the pests. Host-plant resistance can be an important component of the pest-management systems in millets. Emphasis should be placed on the development of repeatable resistance screening techniques. It is important that the new cultivars being released to the farmers are evaluated for susceptibility to the prevalent pest species of a region, and any cultivar tending to support higher insect populations than those currently grown should not be released for cultivation on a large scale. Newer cultivars should rather be selected under natural un-sprayed conditions. This would discourage the selection and release of cultivars susceptible to insect pests. Screening and selecting for pest resistance should therefore be an integral component of crop improvement programs. Chemical control should preferably be used only to control outbreaks of pests. However, at present, information is only available on the relative toxicity of some insecticides against some insect species under laboratory or field conditions, most of which is confined to conditions in the Indian sub-continent. There is a need to have adequate data on the relative efficacy and economics of the insecticides currently available in a region. Attention should also be paid to the environmental hazards and the problem of insecticide residues in the fodder or grain. Efforts should be made to explore the use of locally available natural products for pest control. Neem, (<u>Azadirachta indica</u>) which is widely distributed both in Asia and Africa, can be usefully exploited for this purpose. This will not only ensure the proper use of natural resources, but reduce environmental and toxicity hazards.

There is also a need to gather more data on the storage pests. Pest species highly injurious to millets should be identified as also the extent of losses caused by them. Emphasis should be placed on developing and popularising small storage structures in rural areas that help reduce the damage by storage pests. Efforts should also be made to identify cultivars that are less damaged by storage pests, and infact, screening and selecting for insect resistance to storage pests should form one of the important components of crop improvement programs.

Among the vertebrate pests, birds, are by far the most damaging to millets. Studies of their biology, behaviour and migration should be taken up regionally and internationally. However, bird control operations should not focus on the mass scale killing, which may disturb the natural balance to the disadvantage of man, since we know that some birds consume millions of insects that are highly destructive on a number of crops. Efforts to minimize bird damage should be focussed on uniform planting, development of cultivars less preferred by the birds, efficient bird scaring devices, discouraging the roosting near the cultivated fields, and the use of bird repellent chemicals. Systematic data on rodents damaging millets should be collected and extent of losses quantified. Various methods of rat control as have been developed by various organizations may be utilized. Efforts may be made to make such control operations relevant to the agro-ecosystems of millet growing areas.

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Table 1. Cultivated millets and closely related wild species of gramineae recorded as hosts of different pest species feeding on millets

| S.No. | Common name | Scientific name | No. of pests recorded |
|---|---|---|---|
| 1 | | *Brachiaria decumbens* Stapf. | 2 |
| 2 | | *Brachiaria purpurascens* (Raddi) Henrard | 2 |
| 3 | | *Bothriochloa bladhii* (Retz.) Blake | 1 |
| 4 | Black kolukattai grass | *Cerchrus biflorus* Roxb. | 1 |
| 5 | Kolukattai grass | *Cerchrus ciliaris* Linn. | 1 |
| 6 | Finger grass | *Chloris barbata* Sw. | 1 |
| 7 | Pangola grass | *Digitaria decumbens* Stent. | 9 |
| 8 | Crab grass | *Digitaria sanguinalis* Scop. | 4 |
| 9 | | *Digitaria scalarum* Chiov. | 1 |
| 10 | | *Digitaria* sp. | 1 |
| 11 | Jungle rice | *Echinochloa colona* Linn. | 1 |
| 12 | | *Echinochloa colonum* Linn. | 3 |
| 13 | Japanese millet | *Echinochloa crusagalli* Beauv. | 9 |
| 14 | Barnyard millet | *Echinochloa frumantacea* Link. | 8 |
| 15 | Finger millet | *Eleusine coracana* Gaertn. | 57 |
| 16 | | *Eleusine indica* Gaertn. | 2 |
| 17 | Teff grass | *Eragrostis brownei* Nees. | 1 |
| 18 | | *Eragrostis(abyssinica)teff* Trotter | 1 |
| 19 | | *Hemarthria altissima* Stapf and Hubb. | 1 |
| 20 | | *Hemarthria uncinata* Reg. | 1 |
| 21 | Witch grass | *Panicum anabaptistum* Steud. | 1 |
| 22 | | *Panicum capillare* Linn. | Un-specified |
| 23 | Fall panicum | *Panicum dichotomilflorum* Michx. | 3 |
| 24 | Guinea grass | *Panicum maximum* Jacq. | 2 |
| 25 | Proso millet | *Panicum miliaceum* Linn. | 12 |
| 26 | Little millet | *Panicum miliare* Lam. | 14 |
| 27 | Torpedo grass | *Panicum repens* Linn. | 1 |
| 28 | Switch grass | *Panicum virgatum* Linn. | 1 |
| 29 | | *Panicum* sp. | 5 |
| 30 | | *Oplismenus* sp. | 1 |
| 31 | Dallis grass | *Paspalum dilatatum* Poir. | 2 |
| 32 | Knot grass | *Paspalum distichum* Linn. | 3 |
| 33 | Bahia grass | *Paspalum notatum* Fluegge | 2 |
| 34 | | *Paspalum orbiculare* Forst. | 1 |
| 35 | Kodo millet | *Paspalum scrobiculatum* Linn. | 11 |
| 36 | | *Paspalum scribnerianum* Steud. | 1 |
| 37 | | *Paspalum* sp. | 3 |
| 38 | | *Pennisetum alopecuroides* Spreng. | 1 |
| 39 | Pearl millet | *Pennisetum americanum*(Linn.) Leeke | 403 |
| 40 | KiKuya grass | *Pennisetum clandstinum* Bochst. | 1 |
| 41 | Napier grass | *Pennisetum purpureum* Sch. | 1 |
| 42 | | *Pennisetum* sp. | 1 |
| 43 | | *Rottboellia exaltata* Linn. | 1 |
| 44 | | *Setaria faberii* Herrm. | 1 |
| 45 | Foxtail millet | *Setaria italica* Beauv. | 12 |
| 46 | | *Setaria splendida* Stapf. | 2 |
| 47 | | *Setaria tomentosa* Kunth. | 1 |
| 48 | Bur Bristle grass | *Setaria verticillata* Beauv. | 1 |
| 49 | Green Bristle grass | *Setaria viridis* Beauv. | 4 |
| 50 | | *Setaria* spp. | 2 |

Table 2. Insect and mite pests feeding on millets

| S.No. | Common name | Scientific name | Nature of damage | Distribution | Reference |
|---|---|---|---|---|---|
| | | | 1. ROOT FEEDING INSECTS | | |
| | | Coleoptera:Scarabaeidae (Melolonthinae) | | | |
| 1. | White grub | Holotrichia consanguinea Blanch. | Grubs damage the roots resulting in drying and lodging of the plants. The adults feed on the leaves of many host plants. | India | Patel and Patel 1953; Jotwani et al. 1971; Patel et al 1977; Verma 1975; Srivastava et al. 1971b; Bindra and Singh 1971; Roshanlal et al. 1976; FAO 1972 |
| 2. | " | H.(insularis) reynaudi Bren. | " | India | Jotwani and Butani 1978 |
| 3. | " | H.serrata Blanch. | " | India | Jotwani and Butani 1978; Krishnaswamy et al. 1963; Majumdar and Teotia 1965 |
| 4. | " | H.trichophora Fairm. | " (Recorded on S. italica) | China | Anonymous 1982 |
| 5. | " | Lachnosterna fissa Bren. | " (Recorded on E. coracana) | India | FAO 1972 |
| 6. | " | L. longipennis Blanch. | " (Also recorded on E. coracana) | India | FAO 1972 |
| 7. | " | Holotrichia spp | " (Recorded on E. coracana and E. frumantacea) | India | Rangarajan 1966; Shah and Garg 1982 |
| | | Coleoptera:Scarabaeidae (Rutelinae) | | | |
| 8. | " | Anomala dimidiata Hope | " (Recorded on E. frumantacea) | India | Shah and Garg 1982 |
| 9. | " | Anomala sp | " | India | FAO 1972 |
| 10. | " | Apogonia sp | " | India | Sharma and Davies 1982 |
| 11. | Black beetle | Heteronychus arator Fab. | " (Recorded on P. clandestinum) | New Zealand | Blank et al. 1978; Blank and Olson 1979 |
| | | Coleoptera:Tenebrionidae | | | |
| 12. | False wireworm | Arthrodes sp | Grubs damage the roots (Also recorded on E. corascana) | Southern India | Rangarajan 1965; David and Kumaraswami 1975 |

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| 13. | " | <u>Gonocephalum</u> <u>dorsogranosum</u> Frm. | The grubs feed on germinating seeds and seedlings. The adults nibble the leaves of pearl millet, sorghum, and pigeonpea. | India | Sharma and Davies 1982 |
| 14. | " | <u>G</u>. <u>hoffmannseggi</u> Stev. | " (Also recorded on <u>E</u>. <u>coracana</u>) | India | Coleman 1920; Nair 1975 |
| 15. | " | <u>G</u>. vagum Stev. | " | India | Sharma and Davies 1982 |
| | | Hemiptera:Aphididae | | | |
| 16. | " | <u>Aphis</u> <u>avenae</u> Fab. | Adults and nymphs suck sap from roots resulting in withering and yellowing of the plants | India | Nair 1975 |
| 17. | Sugarcane root aphid | <u>Forda</u> <u>orientalis</u> George | " | India | Jasmine and Ananthanarayana 1975; Jotwani and Butani 1978 |
| 18. | Root aphid | <u>Geocia</u> sp | " | India | Nair 1975 |
| 19. | Root aphid | <u>Rhopalosiphum</u> <u>rufiabdominalis</u> Sas. | " | India | Reddy and Davies 1979 |
| 20. | Ragi root aphid | <u>Tetraneura</u> <u>kalimpongenesis</u> sp n. | " (Recorded on <u>Pennisetum</u> sp) | India | Raychaudhari et al. 1978 |
| 21. | " | <u>T</u>. (hirsuta) nigriabdominalis Sas. | " (Recorded on <u>E</u>. <u>coracana</u>) | India | Gadiyappanavar and Channabasavanna 1973; Chandrasekaran et al. 1975 |
| | | Hemiptera:Cydnidae | | | |
| 22. | Root bug | <u>Stibaropus</u> <u>minor</u> Fab. | Adults and nymphs suck sap from roots in sandy soils | India | Jotwani and Butani 1978; Srivastava and Siddiqui 1967; Kadam and Patel 1960 |
| | | Hymenoptera:Formicidae | | | |
| 23. | Black ant | <u>Monomorium</u> <u>indicum</u> Forel | Remove seeds from the seedbed and store them in the nest leading to low plant stand | India | Jotwani and Butani 1978 |
| 24. | " | <u>Sima</u> sp nr. <u>longiceps</u> Forel | " (Recorded on <u>S</u>. <u>italica</u>) | India | Paul 1982 |
| | | Isoptera:Termitidae | | | |
| 25. | Termite | --- | Feed on roots and burrow through shoot. Affected plants dry up and lodge. | India | Jotwani and Butani 1978; Ratnaswamy 1961 |

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| 26. | " | Microtermes obesi Holmgr. | " (Also recorded on P. miliaceum) | India | Kushwaha et al. 1980; Yazdani 1982 |
| 27. | " | Microtormes sp | " | West Africa | Gahukar 1984 |
| 28. | " | Odontotermes obesus Ramb. | " (Also recorded on P. miliaceum) | India | Yazdani 1982 |
| 29. | " | O. wallonensis Wasn. | " (Recorded on E. coracana) | India | Rajagopal and Veeresh 1983 |
| | | Lepidoptera:Pyralidae | | | |
| 30. | Sugarcane root borer | Emmalocera depresella Swin. | Larvae feed on stem below soil surface. | India | Jotwani and Butani 1978 |
| | | | 2.2. SEEDLING AND SHOOT PESTS | | |
| | | Oiptera:Anthomyiidae | | | |
| 31. | | Hylemyia arambourgi Seguy. | Larvae feed inside the seedlings and produce a dead heart. | Africa | Hill 1975 |
| 32. | | Hylemyia sp | " | Japan | Kobayashi 1946 |
| | | Diptera:Cecidomyiidae | | | |
| 33. | Rice gall midge | Orseolia oryzae Wood-Mason | Larvae feed on the seedlings and produce a silver shoot (Recorded on Paspalum sp) | Thailand | Hidaka et al. 1979 |
| 34. | Gall midge | Orseolia sp | " (Recorded on P. miliare and P. scrobiculatum) | India | Katiyar 1982; Maiti 1982 |
| | | Diptera:Chloropidae | | | |
| 35. | " | Aprometopis flavofacies Bek. | " | Nigeria | Deeming 1971 |
| 36. | " | Elachiptereicus abessynicus Beck. | Larvae feed inside the seedlings | Africa | Vercambre 1976; Deeming 1971 |
| 37 | " | Polyodaspis sp | " | Nigeria | Deeming 1971 |
| 38. | " | Oscinella sp | " (Recorded on D.sanguinalis and Panicum dichotomiflorum) | America | Beisler et al. 1977 |
| | | Diptera:Diopsidae | | | |

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| 39. | Shoot fly | *Diopsis macrophthalma* Dalm. | " (Recorded on *Paspalum orbiculare*) | Nigeria | Alghali 1979 |
| 40. | " | *D. collaris* West. | " (Recorded on *P.pedicellatum*) | Nigeria | Deeming 1982 |
| 41. | " | *Inopus rubriceps* Macq. | " (Recorded on *Paspalum dilatatum*) | New Zealand | Gerard and Parr 1977 |
| | | Diptera:Muscidae | | | |
| 42. | Pearl millet shoot fly | *Atherigona approximata* Malloch | The maggots feed on apical meristem and produce a dead heart. Attack also continues upto heading stage which affects the seed set | India Africa | Malloch 1925; Jotwani et al. 1969c; Jotwani and Singh 1971; Natarajan et al. 1973; Singh and Jotwani 1973; Anon. 1973 ab; Sharma and Bhagirath Singh 1974; Talati and Upadhyay 1978; Regupathy and Balasubramanian 1978; Hill 1975 |
| 43. | Shoot fly | *A. biseta* Karl. | " (Recorded on *S.italica*) | China | Cheng et al. 1983 |
| 44. | " | *A. bituberculata* Malloch | " (Recorded on *P. miliaceum* and *P.scrobiculatum* | India | AICMIP 1969; Jotwani et al. 1969c; Katiyar 1982 |
| 45. | " | *A.destructor* Malloch | " (Recorded on *P.miliaceum* *E.coracana* and *P.* miliare) | India | Rao 1925; Sinha 1962; Natarajan et al. 1974; Selvaraj et al. 1974 |
| 46. | " | *A. falcata* Thom | " (Recorded on *P. miliare* and *E. frumantacea* | India | Reddy and Davies 1977 |
| 47. | " | *A. lineata* Adam | " | Senegal | Gahukar 1985 |
| 48. | " | *A. miliaceae* Malloch | " (Recorded on *P. miliare*, *P. miliaceum*, and *E. coracana*) | India<br>China | AICMIP, 1969; Jotwani et al. 1969c;<br>Wenm 1981 |
| 49. | " | *A. nudiseta* Malloch | " (Recorded on *E. frumantacea* and *E. colona*) | India | AICMIP 1969; Jotwani et al. 1969C; Kundu and Prem Kishore 1971 |
| 50. | " | *A. orientalis* Sch. | " | Senegal | Gahukar 1985 |
| 51. | " | *A. oryzae* Malloch | " (Recorded on *E. frumantacea* | India | Reddy and Davies 1977 |

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| | | | and P. scrobiculatum | | |
| 52. | " | A. penti spn. | " | Nigeria | Deeming 1971 |
| 53. | " | A. pulla Wied. | " (Recorded on E. frumatacea and P. scrobiculatum | India | Reddy and Davies 1977 |
| 54. | " | A. simplex Thom. | " (Recorded on P. scrobiculatum | India | Patel and Rawat 1982 |
| 55. | Sorghum shoot fly | A. soccata Rond. | (Also recorded on D. scalarum, E. coracana, E. frumantacea, P. scrobiculatum, Panicum maximum, P. miliaceum, S. verticillata, and Rottboellia exaltata | India Africa | Moiz and Naqvi 1969; Srivastava et al. 1976; Jotwani et al. 1969C; Hill 1975; Ogwaro 1978; Sharma et al. 1980 |
| 56. | " | A. yorki sp n. | " | Nigeria | Deeming 1971 |
| 57. | " | Atherigona sp | " (Recorded on P.miliaceum, E. frumantacea and S. italica) | India Africa Japan | Ballard and Rao 1924; Young 1971; AICMIP 1968; Vercambre 1976; Jotwani et al. 1969C; Anon. 1973a; Shah and Garg 1982; Yazdani 1982 |
| | | Lepidoptera:Noctuidae | | | |
| 58. | Maize stem borer | Busseola fusca Fuller | Larvae feed on leaves and shoot producing a deadheart. Feeding during the later stages of plant growth leads to stem tunnelling and chaffy heads. (Also recorded on E. coracana) | Africa | Lefervse 1935; Ingram 1958; Harris 1962; Appert 1964; Racbie and Peters 1977 |
| 59. | Stem borer | Manga basilinea Bowden | " (Recorded on P. purpureum) | Africa | Bowden 1956 |
| 60. | " | Poecopa mediopuncta sp n. | " | Ghana | Bowden 1956 |
| 61. | " | Sesamia calamistis Hmps. | " (Also recorded on E. coracana) | West Africa | Harris 1962; Ndoye et al. 1986 |
| 62. | " | S. cretica Led. | " | Africa | Gahan 1928; Bedford 1936a; Tams and Bowden 1953; Nepveu 1950; Abul-Nasr et al. 1968 |

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| 63. | Pink stem borer | S. *inferens* Wlk. | " (Also recorded on P. *scrobiculatum*, E. *frumantacea*, and E. *coracana*) | Asia and Africa | Gahan 1928; Bedford 1936a; Tams and Bowden 1953; Krishnamurty and Usman 1952; Katiyar 1982; Shah and Garg 1982; Garg and Tandon 1983 |
| 64. | " | S. *nonagrioides botanephaga* T. & B. | " | Africa | Gahukar 1984 |
| 65. | Stem borer | S. *penniseti* T. & B. | " | Africa | Appert 1964 |
| 66. | " | S. *poephaga* T. & B. | " | Africa | Appert 1964 |
| 67 | " | *Sesamia* sp | " | Africa | Breniere 1971 |
| | | **Lepidoptera:Pyralidae** | | | |
| 68. | Pearl millet stem borer | *Acigona ignefusalis* Hmps. | " | Africa | Harris 1962; Appert 1964; Breniere 1971; Vercambre 1976 |
| 69. | " | *Chilo diffusilineus* de Joannis | " | Senegal | Bonzi 1982 |
| 70. | " | *Chilo indicus* Kapur | " | India | Nagarkatti and Nair 1973 |
| 71. | " | C. *orichalcociliellus* Strand | " (Also recorded on E. *coracana*) | Africa | Hill 1975; Rachie and Peters 1977 |
| 72. | " | C. *panici* Wang and Sung | " (Recorded om P. *miliaceum*) | China | Gu and Li 1983 |
| 73. | Spotted stem borer | C. *partellus* Swin. | " (Also recorded on E. *coracana* | India Africa | Fletcher and Ghosh 1920; Issac 1946; Ahmed and Young 1969; Sandhu et al. 1976; Nye 1960; Fletcher 1914; Pant and Kalode 1964; Sharma and Chaudhary 1974; Rachie and Peters 1977; Pant al. 1961; Singh and Tiwary 1979; Srivastava et al. 1976. |
| 74. | " | C. (*simplex* Btlr.) *suppressalis* Wlk. | " (Also recorded on E. *crusgalli*) | Uganda Iran | Ingram 1958; Rezwany and Schahosseini 1977 |
| 75. | " | *Chilotrea argyrolepia* Hmps. | " | Nigeria | Harris 1962 |
| 76. | Sugar cane borer | *Diatraea saccharalis* Eguchi | " | Japan | Eguchi 1933 |
| 77. | " | D. *grandiosella* Dyar | " | USA | Burton et al. 1982; Starks et al. 1982a |
| 78. | Sugar cane stem borer | *Eldana saccharina* Wlk. | " | Africa | Harris 1962 |

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| 79. | Stem borer | Saluria inficita Wlk. | " | India | Nair 1975 |

### 1.3. GENERAL DEFOLIATORS

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| | | Coleoptera:Buprestidae | | | |
| 80. | Leaf beetle | Sternocera laevigata Oliv. | General leaf feeder and defoliator. | India | Sharma and Davies 1982 |
| | | Coleoptera:Chrysomelidae | | | |
| 81. | " | Acanthotrachelus sp | " | India | Sharma and Davies 1982 |
| 82. | " | Altica caerulea Oliv. | " | India | Sharma and Davies 1982 |
| 83. | " | Anisostena ariadne Newsm. | " (Recorded on P. virgatum) | USA | Ford and Cavey 1982 |
| 84. | Red pumpkin beetle | Aulacophora foveicollis Lucas. | " | India | AICMIP 1966 |
| 85. | " | A. intermedia Jac. | " | India | Reddy and Davies 1979; Verma 1980 |
| 86. | " | A. nilgiriensis Jac. | " | India | Reddy and Davies 1979; Verma 1980 |
| 87. | Leaf beetle | Chaetocnema basalis Baly | " (Recorded on P. miliare) | India | Maiti 1982 |
| 88. | " | C. concinnipennis Baly | " | India | Sharma and Davies 1982 |
| 89. | " | C. denticulata Ill. | " (Recorded on P. dichotomiflorum) | America | Beisler et al. 1977 |
| 90. | " | C. minuta Jac. | " | India | Sharma and Davies 1982 |
| 91. | " | C. pulicaria Nell. | " (Recorded on P. dichotomiflorum) | America | Beisler et al. 1977 |
| 92. | " | C. tibialis Illig. | " | West Africa | Gahukar 1984 |
| 93. | " | Chaetocnema sp | " (Recorded on E. coracana | India | Rachie and Peters 1977 |
| 94. | " | Dactylispa nigritula Guen. | " | Africa | Demaux 1961 |
| 95. | Rice hispa | Dicladispa armigera Oliv. | " (Also recorded on Echinochloa crusgalli, Echinochloa colonum, and Paspalum distichum | India | Reddy and Davies 1979; Dhaliwal 1979 |

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| 96. | Leaf beetle | Lema planifrons Wls. | " | West Africa | Nwanze 1985 |
| 97. | " | Lema sp | " | West Africa | Gahukar 1984 |
| 98. | " | Leptispa pygamaea Baly | " (Recorded on P. scrobiculatum) | India | Khanvilkar et al. 1983 |
| 99. | Flea beetle | Longitarsus belgaumensis Fab. | " | India | Kapoor et al. 1981 |
| 100. | Leaf beetle | Monolepta signata Oliv. | " (Also recorded on Paspalum distichum) | India | Dhaliwal 1979; Verma 1980; Reddy and Davies 1979 |
| 101. | " | Monolepta sp | " | India Africa | Sharma and Davies 1982; Gahukar 1984 |
| 102. | " | Oulema (Lema) downsei Baly | " (Also recorded on E. coracana) | India | David and Kumarswami 1975; Usman 1967 |
| 103. | " | O. rufotincta Clark | " (Recorded on D. decumbens) | Australia | Broadley and Rogers 1978 |
| 104. | " | Podagris sp | " | West Africa | Gahukar 1984 |
| | | Coleoptera:Coccinellidae | | | |
| 105. | Coccinellid beetle | Epilachna similis Thunb. | " (Also recorded on E. coracana) | Africa | Hill 1975; Rachie and Peters 1977; Sohmutterer 1969 |
| | | Coleoptera:Curculionidae | | | |
| 106. | Leaf beetle | Alcidodes fasbricii Fab. | " | India | Nair 1975 |
| 107. | " | Astychus lateralis Fab. | " | India | Nair 1975 |
| 108. | " | Centrinaspis picumnus Hbst. | " (Recorded on D. sanguinalis) | America | Beisler et al. 1977 |
| 109. | " | Episomus lacerata Fab. | " (Recorded on S. italica) | India | Nair 1975 |
| 110. | " | Madurasia sp | " | India | Paul 1982 |
| 111. | Grey weevil | Myllocerus blandus Faust. | Adults feed on leaves and grubs on roots in the soil. | India | Nair 1975 |
| 112. | " | M. cardoni Marsh. | " (Also recorded on P. purpureum) | India | Pal 1971; Kushwaha et al. 1980; Sachan 1980 |
| 113. | " | M. dentifer Fab. | " | India | Batra et al. 1969; |

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| | | | | | Kushwaha et al. 1980 |
| 114. | " | M. discolor Fab. | " | India | Batra et al. 1969; Kushwaha et al. 1980; Chillar and Verma 1981 |
| 115. | " | M. granulosus Desb. | " | India | FAO 1972 |
| 116. | " | M. lactivirens Mschl. | " | India | Verma 1980 |
| 117. | " | M. undecimpustulatus Faust. | " | India | Batra et al. 1969; Kushwaha et al. 1980 |
| 118. | Cotton grey weevil | M. undecimpustulatus maculosus Desb. | " (Also recorded on P. purpureum) | India | Pande 1971; Singh and Singh 1977; Verma et al. 1969; Shinde et al. 1970; Kapoor et al. 1981; Sachan 1980 |
| 119. | Grey weevil | M. viridanus Fab. | " | India | Batra et al. 1969 |
| 120. | " | Myllocerus spp | " (Recorded on E. coracana) | India | Yadav and Singh 1975 |
| 121. | Leaf beetle | Nematocerus sp | " (Also recorded on E. coracana) | Africa | Hill 1975; Rachie and Peters 1977 |
| 122. | " | Neocleonus sennio Hbst. | " | India | Nair 1975 |
| 123. | " | Pettotrachelus juvenous Faust. | " | India | Sharma and Davies 1982 |
| 124. | " | Phyllobius sp | " | India | Sharma and Davies 1982 |
| 125. | " | Phytoscaphus triangularis Oliv. | " | India | Nair 1975 |
| 126. | " | Ptochus lapsus Mshll. | " | India | Nair 1975 |
| 127. | Gujhia weevil | Tanymecus abyssinicus Hust. | " | Africa | Jannone 1947 |
| 128. | " | T. circumdatus Faust. | " | India | Nair 1975 |
| 129. | " | T. hispidus Faust. | " | India | Nair 1975 |
| 130. | " | T. indicus Faust. | " | India | Bindra and Harcharan Singh 1970 |
| | | Coleoptera:Erotylidae | | | |
| 131. | " | Anadastus fucosus Lewis | " (Recorded on S. italica) | Korea | Nakayama and Tabashi 1933 |
| 132. | " | A. filiformis Fab. | " (Recorded on S. italica) | Japan | Hirose 1935 |
| 133. | " | A. parvulus W. | " (Also recorded on S. italica) | India | Nair 1975 |
| | | Coleoptera:Phalacridae | | | |

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| 134. | " | Phalacris politus Melsh. | " | America | Beisler et al. 1977 |
| 135. | " | Stilbus apicalis Melsh. | " | America | Beisler et al. 1977 |
| | | Coleoptera:Scirtidae | | | |
| 136. | " | Ora picta Fab. | " | India | Sharma and Davies 1982 |
| | | Diptera:Agromyzidae | | | |
| 137. | Leaf miner | Agromyza sp | Larvae feed inside the leaves. | India | Reddy and Puttaswamy 1981 |
| | | Hemiptera:Aphididae | | | |
| 138. | Aphid | Aphis adsuta Zeh. | Adults and nymphs suck sap from the whorl leaves and occasionally in the panicle resulting in stunting and yellowing of the plants. | India | Nair 1975 |
| 139. | " | A. saccharina Zahnt. | " | India | FAO 1972<br>Polynesia |
| 140. | Rusty plum aphid | Hysteroneura setariae Thom. | "<br>(Recorded on S. italica, Setaria spp, E. frumantacea, C. dactylon, Digitaria sp, Oplismensus sp, E. indica, E. coracana, and Peach) | India<br>Taiwan | Saroja et al. 1972; Dasan and Kolandaiswamy 1974; Ramaudiere 1977; Lee and Hsu 1979; Shah and Garg 1982 |
| 141. | Ragi aphid | Macrosiphum eleusines Theo. | " | India | Nair 1975 |
| 142. | " | M. (Sitobion) miscanthi Tak. | "<br>(Recorded on Graminae) | Polynesia | Ramaudiere 1977 |
| 143. | " | M. leelamaniae David | " | India | Nair 1975; Kankaraj 1958 |
| 144. | Corn leaf aphid | Rhopalosiphum maidis Fitch. | "<br>(Also recorded on E. coracana D. decumbens, and P. scrobiculatum) | West Africa<br>India<br>Polynesia<br>Australia | Brandes and Klaphaak 1923; Mandal et al. 1978; Broadley and Rogers 1978; Remaudiere 1977; Ndoye et al. 1986 |
| 145. | Aphid | R. padi Linn. | (Recorded on P. scrobiculatum | Bhutan | Agarwala 1983 |
| 146. | Green bug | Schizaphis graminum Rond. | "<br>(Also recorded on D. decumbens, | America<br>India | Dahms 1951; Daniels 1961; Teitzel and Wilson 1974; Cherian 1933 |

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| | | | B. decumbens, P. maximum, and S. splendida) | | |
| 147. | Aphid | S. hypersiphonata Basu | " (Recorded on D. decumbens) | Australia | Broadley and Rogers 1978; Franzmann 1973a |
| 148. | Sugarcane aphid | Sipha flava Forbes | " (Recorded on D. decumbens, Hemarthria, altissima, and Hemarthria uncinata) | America | Oakes 1978; Starkes and Mirkes 1979 |
| 149. | Aphid | Sitobion avenae Fab. | " (Recorded on Paspalm sp) | Egypt | Elnagar et al. 1980 |
| 150. | " | Sitebion sp | " (Recorded on Setaria sp) | Angola | Stary et al. 1977 |
| | | Hemiptera:Aleyrodidae | | | |
| 151. | Spotted whitefly | Neomaskellia bergii Sign. | " (Also recorded on S. italica) | India | David and Raghunath 1977 |
| | | Bemiptera:Aphrophoridae | | | |
| 152. | Spittle bug | Clovia puncta Wlk. | " | India | Verma 1980 |
| 153 | " | Poophilus costalis Wlk. | " (Also recorded on sorghum) | West Africa India | Reddy and Davies 1979; Bonzi 1981; Ndoye et al. 1986 |
| | | Hemiptera:Cercopidae | | | |
| 154. | Spittle bug | Aeneolamia varia Fab. | " (Recordod on Brachiaria decumbens) | Columbia | Jimenez 1978 |
| 155. | Cercopid | Aeneolamia sp | " (Also recorded om Cenchrus ciliaris) | Mexico | Morales and Enkerlin 1976; Remirez Choza 1978 |
| 156. | " | Prosapia bicincta Say. | " | America | McWilliams and Cook 1975 |
| 157. | Frog hopper | Prosapia simulans Wlk. | " | Mexico | Enkerlin and Schwarts 1977-78 |
| 158. | " | Prosapia sp | " | Mexico | McWilliams and Cook 1975 |
| | | Hemiptera:Cicadellidae | | | |
| 159. | Cicadellid | Apogonalia grossa Sign. | " | Brazil | Menzes 1978 |
| 160. | " | Amrasca sp | " (Recorded on P. purpureum) | India | Sachan 1980 |

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| 161. | " | Balclutha sp | " | India | Khurana and Ramakrishnan 1974 |
| 162. | " | Cicadella spectra Dist. | " | India | Sharma and Davies 1982; Maiti 1982 |
| 163. | Leaf hopper | Cicadulina bipunctella Mats. | " | India | AICMIP 1971 |
| 164. | " | C. mbila Naude | " | South Africa | Rensburg 1982 |
| 165. | " | Cicadulina sp | " (Also recorded on P. purpureum) | India | Verma 1980; Sachan 1980 |
| 166. | " | Empoasca punjabensis Pruthi | " | India | Pruthi 1940 |
| 167. | " | Kella mimica Dist. | " (Recorded on P. miliare) | India | Maiti 1982 |
| 168. | " | Nephotettix nigropictus Stal | " (Recorded on Echinochloa crusgalli and Paspalum distichum) | India | Dhawan and Sajjan 1977 |
| 169. | " | Nephotettix spp | " (Recorded on E. colonum) | India | Mukhopadhaya et al. 1978 |
| 170. | " | Nesoclutha pallida Evans | " (Recorded on E. coracana and E. indica | Australia | Greber 1979a |
| 171. | " | Nisia atrovenosa Leth. | " (Recorded on P. miliare) | India | Maiti 1982 |
| 172. | " | Recilia mica Kramer | " (Also recorded on Paspalum sp) | Ivory Coast | Chenon 1979 |
| 173. | " | Thaia subrufa Motsch. | " (Recorded on E. coracana) | India | Gowda et al. 1983 |
| 174. | " | Zygina sp | " | India | AICMIP 1967 |
| 175. | Maize leaf hopper | Zyginidia guyumi Ahmed | " (Also recorded on D. sanguinalis, E. indica, and S. italica | India | Brar and Singh 1981 |
| | | Hemiptera:Cixiidae | | | |
| 176. | " | Myndus (Haplaxius) crudus van D. | " (Recorded on Paspalum notatum and Panicum purpurascens) | America | Reinert 1977, 1980; Tsai and Kirsch 1978 |
| | | Hemiptera:Coreidae | | | |
| 177. | " | Anoplocnemis curvipes Fab. | " | Sudan | Schmutterer 1969 |
| 178. | " | Cletus punctiger Dallas | " | Japan | Ito 1982 |

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| | | | (Recorded on *E. crusgalli*) | | |
| 179. | " | *C. signatus* Walk. | " | India | Reddy and Davies 1979 |
| 180. | " | *Cletus* sp | " | India | Reddy and Davies 1979 |
| 181. | " | *Mirperus jaculus* Thnb. | " | Sudan | Schmutterer 1969 |
| | | Hemiptera:Cydnidae | | | |
| 182. | " | *Laodelphax striatella* Fall. | " (Also recorded on *S. italica*) | Africa Italy | Hill 1975; Contl 1980 |
| 183. | Rice brown plant hopper | *Nilaparvata lugens* Stal. | " (Recorded on *E. crusgalli*) | Philippines | Saxena and Pathak 1979 |
| 184. | Shoot bug | *Peregrinus* (=*Dicranotropis*= *Pundalouya*) *maidis* Ashm. | " | India | Cherian and Kylasam 1936; Chelliah and Basheer 1965; Rao 1923 |
| 185. | Leaf hopper | *Sogatella furcifere* Horvth. | " (Recorded on *P. miliare* and *E. colonum*) | India | Meiti 1982; Vaidya and Kalode 1981 |
| 186. | " | *S. kolophon* Kirk. | " (Recorded on *D. decumbens*) | Australia | Greber 1979b |
| | | Hemiptera:Fulgoridae | | | |
| 187. | | *Proutista moesta* West. | " | India | Nair 1975 |
| 188. | Sugarcane leaf hopper | *Pyrilla perpusilla* Wlk. | " | India | Jotwani et al. 1969b; Kushwaha et al. 1980 |
| | | Hemiptera:Lygaeidae | | | |
| 189. | Chinch bug | *Blissus leucopterus* Say | Adults and nymphs suck sap from tender leaves. (Also recorded on *P. virgatum*) | America | Reis et al. 1976; Lamp and Holtzer 1980; Starks et al. 1982b; Wilson and Burton 1980 |
| | | Hemiptera:Pseudococcidae | | | |
| 190. | | *Brevennia rehi* Ldgr. | " (Recorded on *Panicum* sp) | America | USDA 1977 |
| 191. | | *Heterococcus nigeriensis* Williams | " | Nigeria | Harris 1960 |
| 192. | | *Heliococcus summervillei* sp n. | " (Recorded on *P. dilatatum*) | Australia | Brookes 1978 |
| | | Hymenoptera:Formicidae | | | |

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| 193. | Leaf cutting ant | Atta laevigata Forel. | Ants cut off the leaves (Recorded on Paspalum notatum) | Guyana | Cherrett et al. 1974 |
| 194. | " | Acromyrmex landolti fracticornis Forel. | " (Recorded on P. maximum and D. smutsi) | Guyana Venezuela Paraguay | Fowler and Robinson 1977; Cherrett et al. 1974; Labrador et al. 1972 |
| | | Orthoptera:Acrididae | | | |
| 195. | Grasshopper | Acrida exaltata Wlk. | The hoppers feed on emerging seedlings and leaves. In case of severe damage, the crop may have to be resown. (Also recorded on P. miliare and E. frumantacea) | India | Sharma and Davies 1982; Maiti 1882; Shah and garg 1982 |
| 196. | " | Acrotylus humbertianus Sauss. | " | India | Reddy and Davies 1979 |
| 197. | " | Acrotylus sp | " (Recorded on E. coracana) | Uganda | Darling 1946 |
| 198. | " | Aiolopus simulatrix simulatrix Walk. | " (Recorded on P. miliare) | India | Reddy and Davies 1979; Maiti 1982 |
| 199. | " | A. tamulus Fab. | " | India | Nair 1975 |
| 200. | " | Atractomorpha crenulata Fab. | " (Also recorded on E. frumantacea) | India | AICMIP 1966; Shah and Garg 1982 |
| 201. | " | Cataloipus sp | " | Sudan | Popov 1959 |
| 202. | " | Cantantops axillaris axillaris Thnb. | " | Sudan | Schmutterer 1969 |
| 203. | " | C. erubescens Walk. | " | India | Reddy and Davies 1979 |
| 204. | " | C. metanostictus Sch. | " (Recorded on E. coracana) | Uganda | Darling 1946 |
| 205. | " | Cantantops sp | " | Nigeria | Dorow 1978 |
| 206. | Surface grasshopper | Chrotogonus oxypterus Blanch. | " | India | Kevan 1954 |
| 207. | " | C. trachypterus Blanch. | " (Also recorded on E. coracana) | India | Coleman 1920; Kevan 1954; Gupta 1972; Verma et al. 1968 |
| 208. | Grasshopper | C. senegalensis abyssinicus Boliv. | " (Recorded on E. coracana) | Uganda | Kevan 1954 |
| 209. | | Chrotogonus spp | " | West Africa | Ndoye et al. 1986 |

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| 210. | Deccan wingless grasshopper | Colemania sphenarioides Boliv. | " (Also recorded on E. coracana | India | Subramanyam 1941; Iyer 1932 |
| 211. | Grasshopper | Cyrtacanthacris ranacea Stoll. | " | India | Nair 1975 |
| 212. | " | C. tatarica Linn. | " | India | Reddy and Davies 1979 |
| 213. | " | Epacromia tamulus Fab. | " | India | Nair 1975 |
| 214. | " | E. dorsalis Fab. | " | India | Nair 1975 |
| 215. | " | Eyprepocnemis alacris alacris Serv. | " | India | Reddy and Davies 1979; Muraligrangan 1978 |
| 216. | " | Gastrimargus africanus Sauss | " | India | Reddy and Davies 1979 |
| 217. | Paddy grass hopper | Hieroglyphus banian Fab. | " (Also recorded on E. frumantacea) | India | Nair 1975; Shah and Garg 1982; Bose et al. 1975 |
| 218. | Grasshopper | H. daganensis Kraus. | " | Sudan West Africa | Popov 1959; Dorow 1978; Schmutterer 1969; Ndoye et al. 1986 |
| 219. | Paddy grasshopper | H. nigrorepletus Boliv. | " | India | Rao and Cherian 1940; Roonwal 1945; Rizvi et al. 1975; Joshi et al. 1976; Peshwani 1960 |
| 220. | Grasshopper | Humbe tenuicornis Sch. | " (Recorded on E. coracana) | Uganda | Darling 1946 |
| 221. | " | Kraussaria angulifera Kraus. | " | Nigeria Sudan | Dorow 1978; Oyidi 1975; Popov 1959; Bindra and Amatobi 1981 |
| 222. | Migratory locust | Locusta migratoria migratorioides R. and F. | " (Also recorded on Echinochloa stagnina, Cenchrus biflorus, and Panicum anabaptistum) | Mali Uganda Sudan | Hargreaves 1939; Ba-Angood 1977; Chabuike 1979; Descamps 1961; Schmutterer 1969 |
| 223. | Grasshopper | Oedaleus nigeriensis Uv. | " (Also recorded on E. coracana) | Africa | Mallamaire 1948; Dorow 1978; Ndoye et al. 1986 |
| 224. | " | O. senegalensis Kraus. | " | Africa | Mallamaire 1948; Bhatia and Ahluwalia 1962, 1966; Schmutterer 1969; Boys 1978; Ndoye et al. 1986 |
| 225. | " | Oedaleus sp | " (Recorded on E. coracana) | Uganda | Darling 1946 |
| 226. | " | Orthacris simulans Boliv. | " | India | Jotwani and Butani 1978 |
| 227. | " | Orthacris sp | " | India | Fletcher 1914 |
| 228. | " | Oxya chinensis Thunb. | " | India | Nair 1975 |

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| 229. | " | O. fuscovitata Marsch. | " (Also recorded on E. frumantacea) | India | Sharma and Davies 1982; Shah and Garg 1982 |
| 230. | " | O. nitidula Walk. | " | India | Reddy and Davies 1979 |
| 231. | " | Oxyina bidentata Willem. | " | India | Verma 1980 |
| 232. | " | Paracomacris sp | " (Recorded on E. coracana) | Uganda | Darling 1946 |
| 233. | " | Patanga succincta Linn. | " | India | Reddy and Davies 1979 |
| 234. | " | Pyrgomorpha bispinosa Wlk. | " | India | Reddy and Davies 1979 |
| 235. | " | Roduniella sp | " (Recorded on E. coracana) | Uganda | Darling 1946 |
| 236. | Desert locust | Schistocerca gregaria Forsk. | Polyphagaus. | India Africa | Maxwell-Darling 1936; Rao 1938; Bhatia 1940; Haroon Khan 1945; Kennedy 1939; Ba-Angood 1977; Jannone 1953; Jackson et al. 1978 |
| 237. | Grasshopper | Spathosternum prasiniferum Wlk. | Nymphs and adults defoliate the crop. | India | Iqbal and Aziz 1975 |
| 238. | " | Sumba sp | " (Recorded on E. coracana) | Uganda | Darling 1946 |
| 239. | " | Teratodus monticollis Cam. | " | India | Sharma and Davies 1982 |
| 240. | " | Zonocerus elegans Thunb. | " (Recorded on E. coracana) | Uganda | Dunbar 1969 |
| 241. | " | Z. variegatus Linn. | " | West Africa | Gahukar 1984 |
| | | Orthoptera:Gryllotalpidae | | | |
| 242. | Cricket | Brachytrypes protentosus Litcht. | " (Recorded on P. miliaceum) | India | Yazdani 1982 |
| 243. | " | Scapsipedus marginatus Afzel and Brann. | Cut stems at ground level. | West Africa | Gahukar 1984 |
| 244. | " | Scapteriscus acletus Rehn & Hebard | " | America | Beck and Skinner 1967 |
| 245. | " | S. vicinus Sud. | " (Recorded on P. notatum) | America | Walker and Deng 1982 |
| | | Orthoptera:Tettigonidae | | | |
| 246. | | Decticoidas brevipennis sp n. | " (Recorded on Eragrostis | Ethiopia | Ragge 1977 |

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| | | | abyssinica) | | |
| 247. | Grasshopper | Homorocoryphus nitidulus vicinus Wlk. | " | Tanganyika | Swaine 1969; Harris 1943 |
| | | Lepidoptera:Arctiidae | | | |
| 248. | Hairy caterpillar | Amsacta lineola Fab. | Feeds on leaves resulting in defoliation. (Recordod on P. scrobiculatum) | India | Nair 1975 |
| 249. | " | A. albistriga Walk. | " (Recorded on E. coracana) | India | Racbie and Peters 1977 |
| 250. | " | A. meloneyi Druca | " | Africa | Varcambre 1976 |
| 251. | Red hairy caterpillar | A. morrei Butl. | " | India | Bindra and Kittur 1956; Patel et al. 1966; Yadava et al. 1966; Pandey et al. 1970; Parihar 1979 |
| 252. | Hairy caterpillar | Creatonotus gangis Linn. | " (Recorded on E. coracana) | India | Raghunath et al. 1978 |
| 253. | Bihar hairy caterpillar | Diacrisia obliqua Walk. | " (Also recorded on E. coracana | India | Jotwani and Butani 1978 |
| 254. | Black hairy caterpillar | Estigmene lactinea Cram. | " (Recorded on E. coracana | India | Nair 1975 |
| | | Lepidoptera:Eupterotidae | | | |
| 255. | Leaf feeding caterpillar | Eupterota translata Swin. | " | India | Reddy and Davies 1979 |
| | | Lepidoptera:Hapialidae | | | |
| 256. | | Dncopera mitocera Turn. | " (Recorded on D. decumbens) | Australia | Quinlan et al. 1981 |
| | | Lepidoptera:Hesperiidae | | | |
| 257. | Rice skipper | Pelopidas (Parnara) mathias Fab. | " | India | Reddy and Davies 1979 |
| 258. | Leaf feeding caterpillar | Telicota colon-colon Fab. | " | India | Reddy and Davies 1979 |
| | | Lepidoptera:Limacodidae | | | |
| 259. | " | Thosea aperiens Wlk. | " (Recorded on E. coracana) | India | Nair 1975 |
| | | Lepidoptera:Lymantriidae | | | |
| 260. | " | Dasychira mendosa Hb. | " | India | Reddy and Davies 1979 |

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| 261. | " | Psalis pennatula Hb. | " | India | Fletcher 1914; Reddy and Davies 1979 |
| | | Lepidoptera:Noctuidae | | | |
| 262. | Cutworm | Agrotis flammatra Schiff. | Damage young seedlings by cutting them at base and feed on leaves. | India | FAO 1972 |
| 263. | " | A. ypsilon Hufn. | " | India America | Hushing and Turppin 1977; Reddy and Davies 1979 |
| 264. | " | A. segetum D. & S. | " | India | Nair 1975 |
| 265. | " | Anticarsia irrotata Fab. | Feed on leaves. | India | Nair 1975 |
| 266. | " | Hyposidra talaca Hufn. | " | India | Nair 1975 |
| 267. | | Mocis latipes Gue. | " (Recorded on P. maximum, P. notatum and P. purpoureum) | Brazil | Lourencao et al. 1982; Silva and Neves, 1984 |
| 268. | Oriental armyworm | Mythimna separata Wlk. | Larvae feed on leaves. During outbreaks there may be complete defoliation of the crop. (Also recorded on S. italica and E. frumantacea | Asia and Australia | Ueno, 1930; Anon, 1976, 1977a; Rai 1971; Bindra and Singh 1973; Balasubramanian et al. 1975; Sharma and Davies 1982, 1983; Sharma et al. 1982; Paul 1982; Shah and Garg 1982. |
| 269. | Armyworm | M. (Viettenia) compta Moore | " | India | Kalode et al. 1971 |
| 270. | " | M. convecta Wlk. | " | Australia | Franzmann 1973b |
| 271. | " | M. loreyi Dup. | " | West Africa India | Ndoye et al. 1986; Sharma et al. 1982; Jhaveri 1920 |
| 272. | Leaf caterpillar | Naranga acnescens Moore | " (Recorded on E. indica) | Philippines | Pantua 1984 |
| 273. | | Plusia signata Fab. | " (Also recorded on E. coracana) | India | Rangarajan et al. 1974; Godse and Patil 1979; Mahanasundram 1972 |
| 274. | " | Pseudaletia sequax Fran. | (Recorded on P. clandestinum) | Brazil | Pereira 1980 |
| 275. | " | Remigia frugalis Fab. | " | India | Nair 1975 |
| 276. | African armyworm | Spodoptera exempta Wlk. | " (Also recorded on E. coracana) | Africa | Rachie and Peters 1977; Ndoye et al. 1986 |
| 277. | | S. exigua Hb. | " (Also recorded on E. coracana) | India Africa | Phadke et al. 1978; Jotwani and Butani 1978; Ndoye et al. 1986 |
| 278. | Fall armyworm | S. frugiperda Smith | " (Also recorded on E. indica and | America | Leuck 1970, 1972; Leuck et al. 1968; Leuck et al. 1977; Escalante 1974; |

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| | | | *D. sanguinalis*) | | Piedra 1974; Ashley et al. 1980; Wiseman and Davies 1979; Pencoe and Martin 1981, 1982. |
| 279. | Egyptian cotton leaf worm | *S. littoralis* Boisd. | " | Africa | Hill 1975 |
| 280. | Tobacco caterpillar | *S. litura* Fab. | " (Also recorded on *P. miliaceum*) | India | Nair 1975; Singh and Vyas 1973; Rao and Sreenivasulu 1984 |
| 281. | | | | | |
| 282. | Rice Swarming Caterpillar | *S. mauritia* Boisd. | " (Also recorded on *D. decumbens*) | India Australia | Nair 1975; Broadley and Rogers 1978 |
| | | Lepidoptera:Pyralidae | | | |
| 283. | Rice leaf folder | *Cnaphalocrocis medinalis* Guen. | " (Recorded on *E. coracana*, *P. miliaceum* and *P. scrodiculatum*) | | Lingappa 1972; Visakantaiah and Jayaramaiah 1972; Velusamy and Subramanyam 1974; Guruswamy Raja and Natarajan 1974; Rao and Srinivasulu 1983 |
| 284. | Lesser corn stalk borer | *Elasmopalpus lignosellus* Zeller | " (Recorded on *D. sanguinalis*; also attacks sorghum) | America | Beisler et al. 1977 |
| 285. | Grass webworm | *Herpetogramma licarsisalis* Wlk. | " | Australia | Murdoch and Tashiro 1976; Broadly and Rogers 1978 |
| 286. | Leaf roller | *Marasmia suspicalis* Wlk. | " (Also recorded on *D. decumbens*) | India | Reddy and Davies 1979 |
| 287. | " | *M. trapezalis* Guen. | " (Also recorded on *S. italica*, *E. coracana* and *P. scrobiculatum*) | India | Jotwani and Butani 1978; Srivastava et al. 1970; Paul 1982; Shah and Garg 1982; Mohanasundaram 1972; Ayquipa and Sirlopu 1975 |
| 288. | | *Lamoria adaptella* Wlk. | " | India | Verma 1980 |
| 289. | | *Loxostege (Pyrausta) massalis* Wlk. | " (Also recorded on *D. decumbens*) | India Australia | Verma 1980 Broadley and Rogers 1978 |
| 290. | | *Pyrausta machaeralis* Wlk. | " | India | Verma 1980 |
| 291. | European borer | *Ostrinia nubilalis* Hb. | " (Recorded on *P. miliaceum*, *S. viridis* and *S. faberii* | Europe | Judenko, 1938; Kokot; 1962; Derozeri et al. 1977; Showers et al. 1980; Manojlovic 1984ab |
| | | Lepidoptera:Saturniidae | | | |

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| 292. | Range caterpillar | Hemileura oliviae Ckll. | " (Recorded on S. italica) | America | Capinera 1978 |
| | | Thysanoptera:Thripidae | | | |
| 293. | Thrips | Baliothrips biformis Bagn. | Lacerate the leaf tissue and feed on the excluding cell sap. The damaged areas dry up. (Recorded on P. repens and rice) | India | Thomas et al. 1979 |
| 294. | " | Florithrips traegardhi Tryb. | " | India | Ananthakrishnan 1971 |
| 295. | " | Heliothrips indicus Bagn. | " (Also recorded on E. coracana) | India | Nair 1975 |
| | | Acarina:Cunaxidae | | | |
| 296. | Mite | Rubroscirus atricanus sp n. | Mites suck sap from the under surface of leaves. | Ethiopia | Heyer 1979 |
| | | Acarinia:Tetranychidae | | | |
| 297. | " | Aceria cyanodeniensis Syed | " (Recordod on P. clandestinum) | South Africa | Meyer 1981 |
| 298. | | A. milli sp n. | " (Recorded on P. miliaceum) | China | Xin and Deng 1982 |
| 299. | | A. paratulipae sp n. | " (Recorded on P. miliaceum) | China | Xin and Deng 1982 |
| 300. | | Eriophyes ladakhensis sp n. | " (Recorded on S. italica) | India | Rishi and Rather 1981 |
| | | Acarina:Tarsonemidae | | | |
| 301. | | Steneotarsonemus biformis Bagn. | " (Recorded on E. crusgalli) | India | Senapaty and Satpathy 1982 |
| 302. | | S. panici sp n. | " (Recorded on P. repens) | India | Mohanasuddram 1984 |
| | | Acarina:Tetranychidae | | | |
| 303. | | Oligonychus indicus Hirst. | " (Also recorded on Setaria viridis) | India China | Sandhu et al. 1975; Ma and Yuan 1980 |
| 304. | | O. digitatus Davis | " (Recorded on P. dandestinum) | Australia | Schida 1981 |
| 305. | Banks grass mite | O. pratensis Banks | " (Recorded on S. viridis and P. alopecuroides) | China | Ma and Yuan 1980 |

## 1.4. EARHEAD PESTS

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| | | Coleoptera:Carabidae | | | |
| 306. | Beetle | <u>Harpalus</u> <u>pensylvanicus</u> Deg. | Adults feed on the earhead (Recorded on <u>S</u>. <u>viridis</u>) | America | Lund and Turpin 1977 |
| | | Coleoptera:Lycidae | | | |
| 307. | | <u>Lycostomus</u> <u>praeusts</u> Fab. | " | India | Sharma and Davies 1982 |
| | | Coleoptera:Meloidae | | | |
| 308. | Blister beetle | <u>Cylindrothorax</u> <u>(Lytta)</u> <u>audouini</u> Haag. | Adults feed on inflorescence | India | Reddy and Davies 1979 |
| 309. | " | <u>C</u>. <u>tenuicollis</u> Pic. | " | India | Reddy and Davies 1979 |
| 310. | " | <u>C</u>. <u>westermanni</u> Mkl. | " | West Africa | Gahukar 1984; Nwanze 1985 |
| 311. | " | <u>Cyaneolytta</u> <u>actaon</u> Lap. | " | India | Dhaliwal et al. 1974 |
| 312. | " | <u>Cyaneolytta</u> spp | " | West Africa | Ndoye et al. 1986 |
| 313. | " | <u>Decapotoma</u> <u>(Mylabris)</u> <u>affinis</u> Billp. | " " | West Africa | Nwanze 1985 |
| 314. | " | <u>Epicauta</u> <u>albovittata</u> Ges. | " | Africa | Hill 1975 |
| 315. | " | <u>E</u>. <u>tenuicollis</u> Pall. | " | India | Singh 1967 |
| 316. | " | <u>Lytta</u> <u>actaeon</u> Cast. | " | India | Nair 1975 |
| 317. | " | <u>L</u>. <u>picta</u> Cast. | " | India | Nair 1975 |
| 318. | " | <u>L</u>. <u>ruficollis</u> Oliv. | " | India | Nair 1975 |
| 319. | " | <u>Mylabris</u> <u>holosericea</u> Klug. | " | West Africa | Gahukar 1984 |
| 320. | " | <u>M</u>. <u>ligata</u> Mars. | " | Sudan | Schmutterer 1969 |
| 321. | " | <u>M</u>. <u>(Zonabris)</u> <u>pustulata</u> Thunb. | " | India | Ramamurty et al. 1970 |
| 322. | " | <u>Mylabris</u> spp | " | Sudan | Schmutterer 1969 |
| 323. | " | <u>Psalydolytta</u> <u>flavicornis</u> Mkl. | " | Africa | Nwanze 1985 |
| 324. | " | <u>P</u>. <u>atricollis</u> Pic. | " | India | Reddy and Davies 1979 |

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| 325. | " | P. fusca Oliv. | " | West Africa | Gahukar 1984 |
| 326. | " | P. rouxi Laporte | " | India | Reddy and Davies 1979 |
| 327. | " | P. theresa Pic. | " | Africa | Nwanze 1985 |
| 328. | " | P. vestita Duf. | " | West Africa | Nwanze 1985; Gahukar 1984 |
| | | Coleoptera:Melyridae | | | |
| 329. | | Melyris abdominalis | Adults feed on the developing grain. | West Africa | Ndoye et al. 1986 |
| | | Coleoptera:Nitidulidae | | | |
| 330. | | Meligethes heteroporus Gers. | Adults on infloresence. | West Africa | Kirk-Spriggs 1985 |
| 331. | | Coleoptera:Scarabaeidae | | | |
| 332. | Chaffer battle | Anomala senegalensis | " | West Africa | Ndoye et al. 1986 |
| 333. | Chaffer beetle | Anatona stillata Newsm. | " | India | Nair 1975 |
| 334. | " | Anthracophora crucifera Ol. | " | India | Sharma and Davies 1982 |
| 335. | " | Chiloloba acuta W. | " | India | Srivastava et al. 1971a |
| 336. | " | Heterorhina elegans Fab. | " | India | Nair 1975 |
| 337. | " | Oxycetonia albopunctata Fab. | " | India | Singh and Rai 1967a |
| 338. | " | O. versicolor Fab. | " | India | Jotwani and Butani 1978; Verma 1980 |
| 339. | " | Pachnoda fairmairei Raffr. | " | Sudan | Schmutterer 1969 |
| 340. | " | P. interrupta Ol. | " | Sudan | Schmutterer 1969 |
| 341. | " | Pachnoda spp | " | Africa | Clarke and Crowe 1978; Gahukar 1984 |
| 342. | " | Protaetia alboguttata Vig. | " | India | Bhatnagar 1970 |
| 343. | " | P. aruchalcea Fab. | " | India | Bhatnagar 1970 |
| 344. | " | P. maculata Fab. | " | India | Bhatnagar 1970 |
| 345. | " | Pseudoprotaetia stolata Oliv. | " | Sudan | Schmutterer 1969 |
| 346. | " | Rhinyptia (reflexa) / infuscata Burm. | " | Africa | Schmutterer 1969; Gahukar and Pierrard 1983 |

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| 347. | " | R. laeviceps Arrow. | " | India | Yadava et al. 1973; Singh and Harjai 1970; Mishra et al. 1979 |
| 348. | " | R. meriodionalis v. puncticolis Arrow. | " | India | Pal and Sharma 1973; Pal 1976, 1977 |
| 349. | " | Spilophorus sp. | " | India | Verma 1980 |
| | | Diptera:Cecidomyiidae | | | |
| 350. | Midge | Contarinia bothrichloae sp n. | Larvae feed on the developing grain. (Recorded on Bothrichloa bladhii) | Australia | Harris 1979 |
| 351. | " | C. brevipalpis sp n. | " (Recorded on Eragrostis brownei) | Australia | Harris 1979 |
| 352. | Pearl millet midge | Geromyia penniseti Felt. | " | India Africa | Felt 1920, 1921; Bedford 1936b; Coutin and Harris 1968; Pradhan 1971; Young 1971; Bhamburkar and Kaushikkar 1972; Thontadarya and Gowda 1974; Santharam et al. 1976; Harris 1984 |
| 353. | Midge | Diacraeus pennisetivora sp n. | " | Senegal | Deeming 1979 |
| 354. | " | Hyperdiplosis sp | " (Recorded on D. sanguinalis) | America | Beisler et al. 1977 |
| 355. | " | Lasioptera sp | " (Also recorded on S. tomentosa) | Africa India | Coutin and Harris 1968; Gajare et al. 1977 |
| 356. | " | Lestodiplosis sp | " (Also recorded on D. decumbens) | Africa India | Coutin and Harris 1968; Gajare et al. 1977 |
| 357. | " | Stenodiplosis panici Rond. | " (Recorded on Panicum sp) | USSR | Selivanona 1948; Skorokhodov 1947; Kamishnyyi 1935; Ostrovskii 1945, 1946 |
| 358. | " | S. sorghiiHarris | " | Senegal | Coutin and Harris 1974 |
| 359. | " | Stenodiplosis sp | " | West Africa | Ndoye et al. 1986 |
| | | Hemiptera:Coreidae | | | |
| 360. | Rice bug | Leptocorisa (varicorinis) acuta Thunb. | Adults and nymphs suck sap from the developing grain. | India | Jotwani and Butani 1978; Kapoor et al. 1981 |
| 361. | " | L. costalis H. & S. | " | India | Corbett 1923 Malasia |

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| 362. | " | Leptocorisa sp | (Also recorded on E. Colonum) | India Pupae and Guinea | Jotwani and Butani 1978; Sands 1977 |
| | | Hemiptera:Lygaeidae | | | |
| 363. | Lygaeid bug | Elasmolomus (Aphanus) sordidus Fab. | " | India | Singh and Rai 1967b; Sharma and Davies 1982 |
| 364. | " | Graptostethus servus Fab. | " | India | Reddy and Davies 1979 |
| 365. | " | Lygaeus mimus Stal. | " | Sudan | Schmutterer 1969 |
| 366. | Dusky cotton bug | Oxycarenus laetus Kir. | " | India | Singh and Jotwani 1971; Visakantaiah et al. 1972 |
| 367. | " | Oxycarenus sp | " | India | Reddy and Davies 1979 |
| 368. | " | Peritrechus fraternus Uml. | " (Recorded on Panicum sp) | America | USDA 1978 |
| 369. | Milkweed bug | Spilostethus pandurus Scop. | " | Punjab | Sandhu et al. 1974a; Visakantaiah and Gowda 1973 |
| 370. | " | Sbilostethus spp | " | India West Africa | Sharma and Davies 1982; Gahukar 1984; Ndoye et al. 1986 |
| | | Hemiptera:Miridae | | | |
| 371. | Head bug | Calocoris angustatus Leth. | " | India | Ballard 1916; Sharma and Davies 1982 |
| 372. | " | Campylomma livida Reut. | " | India | Sundaran 1983 |
| 373. | " | Campylomma sp. | " | India | Sharma and Davies 1982 |
| 374. | " | Creontiades pallidus Ramb. | " | India Sudan | Sharma and Davies 1982; Schmutterer 1969; Sundaran 1983 |
| 375. | " | Eurystylus bellevoyei Put. and Reut. | " | India | Sharma and Davies 1982 |
| 376. | Mirid bug | Lygus militarius Fab. | " | India | Kapoor et al. 1981 |
| 377. | " | L. simonyi Reut. | " (Mainly a pest on young seedling of (E. coracana) | Uganda | Rachie and Peters 1977 |
| 378. | " | Megacoelum stramineum Wlk. | " | India | Verma 1980 |
| 379. | " | M. esmedorae Ballard | " | India | Sundaran 1983 |
| 380. | " | Taylorilygus vosseleri Popp. | " | Africa | Hill 1975 |

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| | | Hemiptera:Pentatomidae | | | |
| 381. | Stink bug | *Agonoscelis nubila* Fab. | (Adults and nymphs suck sap from the developing grain. Also feed on other tender parts of the plant. | India | Nair 1975 |
| 383. | " | *A. (versicolor) pubescens* Thn. | " (Also recorded on *P.miliare* and *E. frumantacea*) | West Africa | Gahukar 1984; Ndoye et al. 1986 |
| 385. | " | *A. rubrofasciatus* Fab. | " | India West Africa | Nair 1975; Gahukar 1984 |
| 386. | " | *Aspavia armigera* Fab. | " | West Africa | Gahukar 1984; Ndoye et al. 1986 |
| 387. | " | *Aspongopus janus* Wlk. | " | India | Verma 1980 |
| 388. | Painted bug | *Bagrada cruciferarum* Kirk. | " | India | Visakantaiah et al. 1972 |
| 389. | " | *B. hilaris* Burm. | " | India | Tayade et al. 1976; Sandhu 1975; Sandhu et al. 1974; Gupta and Gupta 1970 |
| 390. | " | *Calidea* spp | " | West Africa | Gahukar 1984 |
| 391. | " | *Diploxys* spp | " | " | " |
| 392. | Stink bug | *Dolycoris indicus* Stal. | " (Also recorded on *P. miliare* and *E. rumantacea*) | India | Reddy and Davies 1979; Maiti 1982; Shah and Garg 1982 |
| 393. | " | *Eridema pulchrurus* West. | " | India | Nair 1975 |
| 394. | " | *Eusarcocoris guttifer* Th. | " | India | Nair 1975 |
| 395. | " | *Menida histrio* Fab. | " | India | Nair 1975 |
| 396. | " | *Menida* sp | " | India | Reddy and Davies 1979 |
| 397. | Green bug | *Nezara graminea* Fab. | " | India | Nair 1975 |
| 398. | " | *N. viridula* Linn. | " | India West Africa | Reddy and Davies 1979 Ndoye et al. 1986 |
| 399. | " | *Nezara* sp | " (Also recorded on *P. miliare* and *E. frumantacea*) | India | Maiti 1982; Shah and Garg 1982 |

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| 400. | Stink bug | *Piezodorus bybneri* Gmel. | " | India | Reddy and Davies 1979 |
| 401. | " | *P. rubrofasciatus* Fab. | " | India | Nair 1975 |
| 402. | " | *Tessaratoma* sp | " | India | Reddy and Davies 1979 |
| | | Hemiptera:Pyrrhocoridae | | | |
| 403. | Red cotton bug | *Dysdercus cingulatus* Fab. | " | India | Ahmed 1979 |
| 404. | " | *D. koenigi* Fab. | " | India | Reddy and Davies 1979 |
| 405. | " | *D. superstitiosus* Fab. | " | Nigeria Sudan | Geering 1952; Schmutterer 1969 |
| 406. | " | *D. voelkeri* Sch. | " | West Africa | Nwanze 1985 |
| 407. | " | *Dysdercus* sp | " | Africa | Golding 1928 |
| | | Hymenoptera:Formicidae | | | |
| 408. | Ant | *Messor barbarus* Linn. | Cut off seeds and carry them. | Sudan | Schmutterer 1969 |
| 409. | " | *M. galla* Emery | " | Ivory Coast | Levieux and Diomande 1978 |
| 410. | " | *M. regalis* Emery | " | " | " |
| 411. | " | *Pheidole bicarinata longula* Emery | " (Recorded on *P. seribnerianum*) | America | Ballard and Pruess 1979 |
| | | Lepidoptera:Arctiidae | | | |
| 412. | Head Cater-pillar | *Celama analis* Wileman & West | Feed on developing grain on the earhead. | India | Reddy and Davies 1979 |
| 413. | " | *C. internella* Fab. | " | India | Nair 1975 |
| 414. | " | *Celama* spp | " | West Africa | Gahukar 1984; Ndoye et al. 1986 |
| | | Lepidoptera:Cosmopterygidae | | | |
| 415. | " | *Pyroderces (Sathrobrota) simplex* Wilm. | | India West Africa | Munshi and Mecci 1971; Sandhu et al. 1977; Anon. 1982; Ndoye et al. 1986 |
| | | Lepidoptera:Gelechiidae | | | |
| 416. | " | *Anarsia* sp | | India | David et al. 1962; Sharma and Davies 1982 |

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| | | Lepidoptera:Heliodinidae | | | |
| 417. | " | *Stathomopoda theoris* Meyr. | " (Also recorded on *E. coracana*) | India | Nair 1975 |
| | | Lepidoptera:Lymantriidae | | | |
| 418. | Tent hairy cater-pillar | *Euproctis scintillans* Wlk. | " | India | Nair 1975 |
| 419. | " | *E. subnotata* Wlk. | " | India | Jotwani and Butani 1978 |
| 421. | " | *Euproctis* sp | " | India | Reddy and Davies 1979 |
| 422. | " | *Prothesia (Euproctis) (virguncula* Wlk.) *xantharhoea* Coll. | " (Also recorded on *E. coracana*) | India | David et al. 1962; Vaish and Sharma 1971; Sandhu et al. 1974c; Reddy and Davies 1979 |
| | | Lepidoptera:Noctuidae | | | |
| 423. | Head cater-pillar | *Azazia rubricans* Boisd. | " (Recorded on *P. scrobiculatum*) | India | Guruswamy Raja and Natarajan 1974 |
| 424. | " | *Eublemma silicula* Swin. | " (Also recorded on *E. coracana*) | India | David et al. 1962; Jotwani et al. 1966 |
| 425. | " | *E. gayneri* Roths. | " | Africa India | Anon. 1982; Schmutterer 1969; Ndoye et al. 1986 |
| 426. | Bollworm | *Heliothis armigera* Hb. | " (Also recorded on *E. coracana*) | India Africa | David et al. 1962; Vishakantaiah 1972; Nagesh Chandra 1982; Schmutterer 1969; Singh et al. 1982; Ndoye et al. 1986 |
| 427. | American bollworm | *H. zea* Boddie | " | America | Burton et al. 1977; Leuck et al. 1977 |
| 428. | Head Cater-pillar | *Masalia bimaculata pluritelifora* Berio. | Larvae feed on inflerescence and grains in a spiral manner. | Senegal | Ndoye 1979 |
| 429. | " | *M. cheesmanae cheesmanae* Sey. | " | Senegal | Ndoye 1979 |
| 430. | " | *M. decorata albiseriata* Druce. | " | Africa | Seymour 1972 |
| 431. | " | *M. decorata metarhoda* Durce. | " | Africa | Seymour 1972 |
| 432. | " | *M. galathae galathae* Wall. | " | Africa | Seymour 1972 |
| 433. | " | *M. rubristria rubristria* Hmps. | " | Africa | Seymour 1972 |
| 434. | " | *M. terracottoides* Roth. | " | Africa | Seymour 1972 |

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| 435. | " | Masalia sp | " | Africa | Vercambre 1978; Seymour 1972 |
| 436. | " | Raghuva albipunctella De Joannis | " | Africa | Ndoye 1979 |
| 437. | " | R. bordati sp n. | " | Africa | Laporte 1977 |
| 438. | " | R. brenierei Lap. | " | Africa | Laporte 1977 |
| 439. | " | R. graminivora Lap. | " | Africa | Laporte 1977; Ajay 1984 |
| 440. | " | R. stigmata Hmps. | " | Senegal | Ndoye 1979 |
| 441. | " | R. vercamberci sp n. | " | Senegal | Laporte 1977 |
| 442. | " | Raghuva sp | " | Africa | Vercambre 1978 |
| 443. | " | Simplicia robustalis Gm. | Feed on earheads in the stacks. (Recorded on E. coracana) | India | AICMIP 1967 |
| | | Lepidoptera:Pyralidae | | | |
| 444. | " | Cryptoblabes angustipennella Hmps. | Feed on developing grain in the earhead. | India | Nair 1975 |
| 445. | " | C. gnidiella Mill. | " (Also recorded on E. coracana | India | Reddy and Davies 1979; Srivastava and Singh 1973; Patel et al. 1981 |
| 446. | " | Cryptoblabes sp | " (Recorded on E. coracana) | India | David et al. 1962 |
| 447. | " | Stenochroia elongella Hmps. | " (Also recorded on E. coracana) | India | David et al. 1962; Nair 1975 |
| | | Lepidoptera:Tortiicidae | | | |
| 448. | " | Cacoesia epicyrta Meyr. | " (Recorded on E. coracana) | India | Nageshchandra 1982; David et al. 1962 |
| | | Thysanoptera:Thripidae | | | |
| 448. | Thrips | Anaphothrips (flavicinctus) soudanensis Tryb. | Scrap the panicle/leaf tissue and feed on exuding cell sap. | India | Ananthakrishnan and Jagdish 1968; Kumar and Ananthakrishnan 1984 |
| 450. | " | A. ramakrishna Karny | " (Also recorded on P. maximum) | India | Karny 1926 |
| 451. | " | Chaetanaphothrips orchidii Moulton | " (Recorded on Brachiaria purpurascens) | French West Indies | Delattre and Torregrossa 1978 |
| 452. | " | Caliothrips indicus Bagn. | " | India | Muraleedharan and Ananthakrishnan 1978 |
| 453. | " | C. graminicola Bagn. and Cam. | " | India | Kumar and Ananthakrishnan 1984 |

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| | | | (Recorded on *P. maximum*) | | |
| 454. | " | *Chirothrips maxicanus* Crawford | " (Also recorded on *Chloris barbata* | India | Ananthakrishnan and Tirumalai 1977 |
| 455. | " | *Haplothrips ganglbaueri* Sch. | " (Also recorded on *Echinochloa crusgalli*) | India | Ananthakrishnan and Thangavelu 1976; Jotwani and Butani 1978 |
| 456. | " | *H. gowdeyi* Frank. | " | India | Jotwani and Butani 1978 |
| 457. | " | *Thrips* (*Hawaiiensis* Morg.) *florum* Sch. | " | India | Jotwani and Butani 1978 |
| 458. | " | | " | India | Verma 1980 |

Table 3. Extent of losses and incidence reported on some pests of millets

| Insect | Crop | Avoidable losses(%) | Incidence(%) | Country | Reference |
|---|---|---|---|---|---|
| | | A. ROOT PESTS | | | |
| Arthrodes sp. | E. coracana | - | 25.0-100.0 | India | Rangarajan, 1965 |
| Holotrichia spp. | P. americanum | | 30.0-53.0 | India | Rangarajan, 1966 |
| | | | | | Pradhan, 1971 |
| | | | | | Jotwani, 1978 |
| | | B. SEEDLING AND SHOOT PESTS | | | |
| Atherigona approximata | P. americanum | 9.2-39.0 | - | India | Selvaraj *et al*., 1974 |
| | | 23.3-59.3 | 29.9-66.8 | India | Natarajan *et al*., 1973, 1974 |
| | | 35.3 | 60.3 | India | Singh and Jotwani, 1973 |
| Acigona ignefusalis | P. americanum | - | 7.44 larvae per 100 stems | Nigeria | Harris, 1962 |
| | | - | 20.0 | Senegal | Vercambre, 1976 |
| | | C. FOLIAGE FEEDERS | | | |
| Amsacta meloneyi | P. americanum | - | 30.0 | Senegal | Vercambre, 1976 |
| Bagrada cruciferarum | P. americanum | - | 60 bugs/heed | India | Gupta and Gupta, 1970 |
| Euprctis virguncula | p. americanum | - | 19.0-32.0 | India | Vaish and Sharma, 1971 |
| Lygeas civilis | P. americanum | - | 7-24 bugs/5 heads | India | Sandhu *et al*., 1974a |
| Marasmia trapezalis | P. americanum | - | 0.0-24.0 | India | Pradhan, 1971 |
| Mythimna separata | E. Coracana | - | 47.0-53.0 | India | Balasubramanian *et al*., 1975 |
| | | B. EARHEAD PESTS | | | |
| Chiloloba acuta | P. americanum | - | 0-25 beetles/head | India | Srivastava *et al*., 1971a |
| Chirothrips maxicanus | P. americanum | 5.0-10.0 | 30-48 adults/head | India | Ananthakrishnan and Tirumalai, 1977 |
| Geromyia penniseti | P. americanum | - | 23-219 midges/head | India | Thontadarya and Gowda, 1974 |
| Heliothis armigeria | P. americanum | - | 25.0-28.1 | India | Vishakantaiah, 1972 |
| Masalia spp. and Raghuva spp. | P. americanum | 25.0-50.0 | - | Senegal | Vercambre, 1978 |
| Mylabris pustulata | P. americanum | 6.8 | 25.0-45.0 | India | Ramamurty *et al*., 1970 |
| | | 5.0-50.0 | - | India | Singh and Harjai, 1970 |
| Rhinyptia spp. | P. americanum | - | 14.8 | India | Verma, 1979 |
| Storage pests | P. americanum | 10-60 | - | India, Africa | Rachie and Majmudar, 1980 |
| | | E. VERTEBRATE PESTS | | | |
| Birds | P. americanum | 10.0 | - | India | Jain and Ishwar Prakash, 1974 |
| | | $ 4.5 million | - | Senegal | Bruggers and Ruelle, 1981 |
| | | $ 6.3 million | - | Sudan | Anon. 1981 |
| Rodents | Cereals | 20 | - | Asia, Africa | Hopf *et al*., 1976 |

Table 4. Natural enemies of insect pests feeding on millets

| Insect | Natural enemy | Remarks | Reference |
|---|---|---|---|
| <u>Acigona</u> <u>ignefusalis</u> | Diptera:Chloropidae | | |
| | <u>Ceratopogon</u> <u>risbeci</u> Sequy | Larval parasite | Ndoye et al. 1986 |
| | <u>Epimadiza</u> sp | Larval-pupal parasite | Ndoye et al. 1986 |
| | Diptera:Phoridae | | |
| | <u>Aphiochaeta</u> sp | Larval parasite | Ndoye et al. 1986 |
| | Diptera:Tachinidae | | |
| | <u>Sturmiopsis</u> <u>parasitica</u> Tns. | Larval-pupal parasite | Harris 1962; Ndoye et al. 1986 |
| | Hymenoptera:Bethylidae | | |
| | <u>Goriozus</u> <u>procerae</u> Risb. | Larval parasite | Gahukar 1984; Ndoye et al. 1986 |
| | <u>Goniozus</u> sp | Diapausing larvae | Harris 1962 |
| | Hymenoptera:Braconidae | | |
| | <u>Apanteles</u> <u>sesamiae</u> Cam. | Larval parasite | Ndoye et al. 1986 |
| | <u>Euvipio</u> <u>rufa</u> Szepl. | " | Ndoye et al. 1986 |
| | <u>E.</u> <u>fascialis</u> Szepl. | " | Ndoye et al. 1986 |
| | <u>Glyptomorpha</u> sp | Pupal parasite | Ndoye et al. 1986 |
| | <u>Rhaconotus</u> <u>soudanensis</u> Wlkn. | Larval parasite | Ndoye et al. 1986 |
| | Hymenoptera:Chalcididae | | |
| | <u>Hyperchalcidia</u> <u>soudanonsis</u> Stef. | Pupal parasite | Harris 1962; Ndoye et al. 1986 |
| | Hymenoptera:Encyrtidae | | |
| | <u>Euzkadia</u> sp (? <u>integralis</u> Merc.) | Larval parasite | Ndoye et al. 1986 |
| | Hymenoptera:Eulophidae | | |
| | <u>Pediobus</u> <u>furvus</u> Gah. | Pupal parasite | Ndoye et al. 1986 |
| | <u>Tetrastichus</u> <u>atriclavus</u> Wstn. | " | Harris 1962; Ndoye et al. 1986 |
| | Hymenoptera:Ichneumonidae | | |
| | <u>Chasmias</u> sp | Pupal parasite | Ndoye et al. 1986 |
| | <u>Dentichasmias</u> <u>busseolae</u> Hein | " | Ndoye et al. 1986 |
| | <u>Glyptomorpha</u> sp | Larval parasite | Harris 1962 |
| | <u>Syzeuctus</u> spp | " | Ndoye et al. 1986 |
| | Hymenoptera:Scelionidae | | |

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|---|---|---|---|
| | Platyelenomus hylas Nixon | Egg parasite | Ndoye et al. 1986 |
| | Acarina:Pyemotidae<br>Pyremotes ventricosus Newfs.<br>Fungus | External parasite of diapausing larvae | Harris 1962;<br>Ndoye et al. 1986 |
| | Metarrhizium anisopliae (Met.) Sorokia | Infects lasrvae | Harris 1962; Ndoye et al. 1986 |
| Agromyza sp | Hymenoptera:Braconidae<br>Bracon sp | Recorded on pupae | Reddy and Puttaswamy 1981 |
| | Nematode | | |
| Amsascta moorei | Mermis sp | Recorded on larvae | Bindra and Kittur 1956 |
| Aphids | Coleoptera:Coccinellidae<br>Brumoides suturalis F. | Feeds on nymphs and adults | Reddy and Davies 1979 |
| | Illeis indica Timb. | " | Reddy and Davies 1979 |
| | Menochilus sexmaculatus Fab. | " | Reddy and Davies 1979 |
| | Diptera:Agromyzidae<br>Leucopis sp | " | Cherian 1933 |
| | Hymenoptera:Eulophidae | | |
| Celama analis | Tetrastichus ayyari Roh. | Larval parasite | Reddy and Davies 1979 |
| | Phanerotoma sp | Larval parasite | Anon. 1981a |
| | Hymenoptera:Bethylidae | | |
| Chilo diffusilineus | Goniozus sp | " | Bonzi 1982 |
| | Hymenoptera:Braconidae | | |
| | Apanteles sesamiae Cam. | " | Bonzi 1982 |
| | Hymenoptera:Bethylidae | | |
| | Brachymeria sp | " | Bonzi 1982 |
| | Diptera:Tachinidae | | |
| Chilo partellus | Carcelia sp | " | Reddy and Davies 1979 |
| | Pseudaslsomyia sp | Larval or pupal parasite | Reddy and Davies 1979 |
| | Halidaya luteicornis Wlk. | Larval parasite | Reddy and Davies 1979 |
| | Sturmiopsis inferens Tns. | " | Nair 1975 |

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|---|---|---|
| Thelaira sp | " | Nair 1975 |
| Hymenoptera:Bethylidae | | |
| Goniozus indicus Msb. | " | Nair 1975 |
| Hymenoptera:Braconide | | |
| Apanteles colemani Vier. | " | Nair 1975 |
| Apanteles flavipes Cam. | " | Anon. 1981a |
| Bracon albolineatus Cam. | " | Anon. 1981a |
| Bracon chinensis Szel. | " | Bhatnagar and Davies 1979a |
| Chelonus narayani S. Rao | " | Reddy and Davies 1979 |
| Glyptomorpha deesae Cam. | " | Nair 1975 |
| Iphiaulax spilocephalus Cam. | " | Reddy and Davies 1979 |
| Iphiaulax sp | " | Nair 1975 |
| Rhaconotus roslinensis Lal | " | Nair 1975 |
| Stenobracon deesae Cam. | " | Nair 1975 |
| Stenobracon nicevilles Bing. | " | Nair 1975 |
| Hymenoptera:Chalcididae | | |
| Hyperchalcidia soudanensis Steff. | Pupal parasite | Reddy and Davies 1979 |
| Invreia sp | " | Reddy and Davies 1979 |
| Hymenoptera:Eulophidae | | |
| Tetrastichus ayyari Roh. | Pupal parasite | Reddy and Davies 1979 |
| Hymenoptera:Ichneumonide | | |
| Centeterus alterneco-loratus Cush. | " | Nair 1975 |
| Trathala flavo-orbitalis Cam. | Larval parasite | Reddy and Davies 1979 |
| Xanthopimpla punctata Fab. | Pupal parasite | Nair 1975 |
| Xanthopimpla punctator Linn. | " | Nair 1975 |
| Xanthopimpla stemmator Thunb. | " | Nair 1975 |
| Hymenoptera:Scelionide | | |
| Telenomus sp | Egg parasite | Bhatnagar and Davies 1979a |

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|---|---|---|---|
| | Hymenoptera:Trichogrammatidae | | |
| | *Trichogramma chilonis* Ishii | Egg parasite | Bhatnagar and Davies 1979a |
| | *Trichogramma evanescens minutum* Riley | " | Nair 1975 |
| | *Trichogramma* sp | " | Nair 1975 |
| | Coeleoptera:Coccinellide | | |
| | *Menochilus sexmasculatus* Fab. | Preys upon young larvae | Pradhan 1971 |
| | Diptera:Bombylidae | | |
| *Colemania sphenerioides* | *Systoechus* sp | Egg parasite | Nair 1975 |
| | Coleoptera:Meloidae | | |
| | *Zonabris* sp | " | Nair 1975 |
| | Hymenoptera:Braconidae | | |
| *Estigmene lactinea* | *Apanteles creatonoti* Vier. | " | Reddy and Davies 1979 |
| | Diptera:Tachinidae | | |
| *Euproctis virguncula* | *Carcelia* sp | Larval parasite | Sandhu et al. 1974 |
| | Hymenoptera:Ichneumonidae | | |
| | *Xanthopimpla* sp | Pupal parasite | Sandhu et al. 1974c |
| | Hemiptera:Anthocoridae | | |
| | *Orius* sp | Predator | Coutin and Harris 1968 |
| | Hymenoptera:Ceraphronidae | | |
| *Geromyia penniseti* | *Aphanogmus* sp | Endoparasite | Coutin and Harris 1968 |
| | Hymenoptera:Eulophidae | | |
| | *Tetrastichus diplosidis* | Larval pupal parasite | Ndoye et al. 1986 |
| | *Tetrastichus* sp | | Coutin and Harris 1968 |
| | Hymenoptera:Eupelmidae | | |
| | *Eupelmus popa* Gir | " | Ndoye et al. 1986 |
| | *Eupelmus* sp | " | Coutin and Harris 1968 |
| | Hymenoptera:Platygasteridae | | |

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|---|---|---|---|
| | Platygaster sp | " | Coutin and Harris 1968 |
| | Hemiptera:Anthocoridae | | |
| Haplothrips ganglbaueri | Orius sp | Predator | Reddy and Davies 1979 |
| | Diptera:Tachinidae | | |
| Heliothis armigera | Goniophthalmus halli Mes. | Larval parasite | Anon. 1981c |
| | Hymenoptera:Bethylidae | | |
| | Goniozus sp | " | Anon. 1981c |
| | Hymenoptera:Braconidae | | |
| | Microchelonus curvimaculatus Cameron | " | Anon. 1981c |
| | Hymenoptera:Ichneumonidae | | |
| | Barichneumon sp | " | Anon. 1981c |
| | Campoletis chlorideae Uchida | " | Anon. 1981c |
| | Eriborus argenteopilosus Cameron | " | Anon. 1981c |
| | Temelucha sp | " | Anon. 1981c |
| | Hymenoptera:Trichogrammatidae | | |
| | Trichogramma sp | Egg parasite | Bhatnagar 1983 |
| | Diptera:Sarcophagidae | | |
| Kraussaria angulifera | Sarcophaga schoemani Zumpt. | Adult parasite | Bindra and Amatobi 1981 |
| | Hymenoptera:Scelionidae | | |
| | Scelio howardi Gaw. | " | Bindra and Amatobi 1981 |
| | Diptera:Tachinidae | | |
| Mythimna separata | Carcelia sp | Larval/pupal parasite | Sharma et al. 1982 |
| | Exorista xanthaspis Wied. | " | Sharma et al. 1982 |
| | Palexorista solemnis Wlk. | " | Sharma et al. 1982 |
| | Palexorista sp | " | Sharma et al. 1982 |
| | Hymenoptera:Braconide | | |
| | Apanteles ruficorus Hal. | Larval parasite | Sharma et al. 1982 |
| | Disophrys sp | " | Sharma et al. 1982 |

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|---|---|---|---|
| | Hymenoptera:Ichneumonidae | | |
| | _Metopius_ sp | " | Sharma et al. 1982 |
| | Hymenoptera:Bethylidae | | |
| _Marasmia trapezalis_ | _Goniozus marasmi_ K. | " | Nair 1975 |
| | Coleoptera:Coccinellidae | | |
| _Olygonychus indicus_ | _Stethorus pauperculus_ Wse. | Predator | Reddy and Davies 1979 |
| | Acarina:Phytosoiidae | | |
| _Oligonychus digitatus_ | _Amblyseius benzamini_ sp n | " | Schida 1981 |
| | Diptera:Tachinidae | | |
| _Pelopidas mathias_ | _Thecocarcelia_ sp | Pupal parasite | Reddy and Davies |
| | Hymenoptera:Braconidae | | |
| | _Apanteles_ sp 'Glomeratus' group | Larval parasite | Reddy and Davies 1979 |
| | Hymenoptera:Chalcididae | | |
| | _Brachymeria_ sp nr. (_eulopeae_) West. | " | Reddy and Davies 1979 |
| | Hymenoptera:Eulophidae | | |
| _Peregrinus maidis_ | _Ootetrastichus indicus_ G. | Egg parasite | Nair 1975 |
| | Hymenoptera:Mymaridae | | |
| | _Anagrus_ _(=Paranagrus)_ _optabilis_ Perk. | " | Nair 1975 |
| | Diptera:Syrphidae | | |
| _Poophilus costalis_ | _Asarkina ericetorum_ Fab. | Predator | Bonzi 1981 |
| | Diptera:Tachinidae | | |
| _Psalis pennatula_ | _Carcelia_ sp | Larval parasite | Reddy and Davies 1979 |
| | Diptera:Bombyliidae | | |
| _Raghuva albipunctella_ | _Thyridanthrax_ sp nr. _kappa_ Bowden | Pupal parasite | Ndoye et al. 1986 |
| | Diptera:Tachinidae | | |
| | _Goniophthalmus halli_ Mes. | Larval parasite | Gahukar 1985; Ndoye et al. 1986 |
| | Hemiptera:Anthocosidae | | |

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|---|---|---|
| Orius sp | Predates on eggs and larvae | Ndoye et al |
| Hemiptera:Pentatomidae | | |
| Glypsus conspicuus West. | Predates on larvae | Ndoye et al. 1986 |
| Hemiptera:Reduviidae | | |
| Ectomocoris fenestratus Flug. | Predates on larvae | Ndoye et al. 1986 |
| Coleoptera:Carabidae | | |
| Chlaenius boisduvalli Dejean | Predates on larvae | Ndoye et al. 1986 |
| C. dusaultii Dufour | " | Ndoye et al. 1986 |
| Pheropsophus sp nr. lafertei Arrow. | " | Ndoye et al. 1986 |
| Hymenoptera:Bethylidae | | |
| Goniozus sp | Larval parasite | Ndoye et al. 1986 |
| Hymenoptera:Braconidae | " | " |
| Apanteles sp (ultor group) | " | Ndoye et al. 1986 |
| Bracon hebetor Say | " | Gahukar 1985; Ndoye et al. 1986 |
| Cardiochiles sp | " | Ndoye et al. 1986 |
| Hymenoptera:Chalcididae | | |
| Non-identified | " | Ndoye et al. 1986 |
| Hymenoptera:Encyrtidae | | |
| Litomastix sp | " | Ndoye et al. 1986 |
| Hymenoptera:Eumenidae | | |
| Non-identified | Predates on pupae | Ndoye et al. 1986 |
| Hymenoptera:Formicidae | | |
| Non-identified | " | Ndoye et al. 1986 |
| Hymenoptera:Ichneumonidae | | |
| Hadromanus sp | Pupal parasite | Ndoye et al. 1986 |
| Hymenoptera:Trichogrammatidae | | |
| Trichogramma sp | Egg parasite | Bhatnagar 1983 |

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|---|---|---|---|
| | Trichogrammatoidea sp | " | Ndoye et al. 1986 |
| | Hymenoptera:Vespidae | | |
| | Polistes sp | Predates on larvae | Ndoye et al. 1986 |
| | Nematoda:Mermithidae | | |
| | Hexamermis sp | Larval parasite | Ndoye et al. 1986 |
| | Fungus: | | |
| | Aspergillus flavus Link. | " | Ndoye et al. 1986 |
| | Aspergillus sp (ochraceus group) | " | Ndoye et al. 1986 |
| | Bacteria: | | |
| | Bacillus thuringiensis | " | Ndoye et al. 1986 |
| | Hymenoptera:Chalcididae | | |
| Sesamia calamistis | Brachymeria feae Masi | Recorded from pupae | Harris 1962 |
| | Hymenoptera:Braconide | | |
| Sesamias cretica | Apanteles ruficrus Haliday | Larval parasite | Gahan 1928 |
| | Diptera:Tachinidae | | |
| Sesamia inferens | Sturmiopsis inferens Tns. | Larval parasite | Bhatnagar and Davies 1979a; Anon. 1981a |
| | Hymenoptera:Ichneumonidae | | |
| | Xanthopimpla sp | " | Nair 1975 |
| | Hymenoptera:Scelionide | | |
| | Telenomus sp | Egg parasite | Nair 1975 |
| | Hymenoptera:Trichogrammatidae | | |
| | Trichogramma minutum Riley | " | Nair 1975 |
| | Hymenoptera:Eulophidae | | |
| Sesamia penniseti | Pediobius furvus Gah. | Pupal parasite | Harris 1962 |
| | Hymenoptera:Eulophidae | | |
| Sesamia poephaga | Pediobius furvus Gah. | " | Harris 1962 |
| | Pediobius sp near hirtellus | " | Harris 1962 |

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|---|---|---|---|
| | Diptera:Tachinidae | | |
| Sesamia sp | Sturmiopsis parasitica Tns. | " | Harris 1962 |
| | Hymenoptera:Braconidae | | |
| | Apanteles flasvipes Cam. | Larval parasite | Nair 1975 |
| | Apanteles sesamiae Cam. | " | Harris 1962 |
| | Bracon chinensis Sze. | " | Nair 1975 |
| | Hymenoptera:Eulophide | | |
| | Pediobius furvus Gah. | Pupal parasite | Harris 1962 |
| | Tetrastichus atriclavus Wstn. | " | Harris 1962 |
| | Tetrastichus ayyari Roh. | " | Harris 1962 |
| | Hymenoptera:Pteromalidae | | |
| | Norbanus sp | " | Harris 1962 |
| | Fungus | | |
| Spodoptera exigua | Nomuraea rileyi (Farlow) Samson. | | Phadke et al. 1978 |

Table 5. Resistant/less susceptible lines of millets reported against various insect-pests

| S.No. | Insect | Line | Remarks | Reference |
|---|---|---|---|---|
| 1. | A. ignefitalis | Zongo | - | Gahukar 1984 |
| | | INMB 106, INMB 218, INMB 155 | Tolerant to stem borer | Ndoye et al. 1986 |
| 2. | White grubs | IP Nos. 478, 476, 513, 256, 323, 213, 514, 253, 432, RSJ, 225, 467, HB-2, 375, 18A, J88, 23A, 205, 315, 427, 501, 242 2A and 314 | Lines found highly promising under natural incidence of white grubs | Pradhan 1971 |
| 3. | B. leucepterus | Big red (P. miliaceum) | Tolerance | Wilson and Burton 1980 |
| 4. | C. partellus | A-10, A 21P1, A 63, A 66, A 163, A 280 and A 281 | Least susceptible lines (<25% incidence) | Sandhu et al. 1976 |
| | | PES 172, KM 1, KM1 14, PR 202, LES 224, and IE 169 (E. coracama) | Less damaged | Kundu et al. 1980 |
| 5. | S. inferens | VR 94, C 180, PR 722 and S 81-10<br>PES 9, JNR 1008, KM 1, PES 224, HR 228, T 36B, PES 144, and KM 14 (E. coracana) | Less susceptible | Jotwani 1978<br>Kishore and Jotwani 1980 |
| 6. | A. approximata | 23 D2A x H 403 suffered least and 628A x KS 75-7 highest incidence among 30 hybrids tested | All hybrids were highly susceptible | Natarajan et al. 1973 |
| | | 5141A x PT 1939, IP 241, PT 1939, MS 6317, PT 1522, PT 1930, IP 863, PT 1836, and MS 6112 | Less susceptible | Appadurai et al. 1981 |
| 7. | S. frugiperda | Tift 23 S | Ovipositional non-preference related to the absence of foliage pubescence | Burton et al. 1977<br>Leuck et al. 1977 |
| | | P 1176653 (P. miliaceum) | Resistant | Wilson and Courteau 1984 |
| | | Inbred 240 | Resistant | Wiseman and Davies 1979 |
| | | Gahi cultivar | Moderately resistant | Leuck et al. 1968 |
| 8. | S. graminum | Gahi 1 | Resistant | Stegmier and Harvey 1976 |
| 9. | M. separata | Souga Local 4,700112, PIB 228, AND D 1051 I | Less damaged compared to the susceptible check SAR 57 | Sharma and Davies 1982 |
| 10. | M. Maculosis | NHB 5 | Less damaged | Singh and Singh 1977 |
| | | HR 374, JAN 852, B7-43, PR 1044, PES 8, PES 176, Indaf 5, T20-1, PES 144, CO 10, and KM 14 (E. coracana) | Less damaged | Kishore and Jotwani 1980 |
| 11. | P. purpusilla | IP Nos 22B, 36D, 44, 79, 214, 263, 1266, | Contained <1 egg mass/plant | Pradhan 1971 |

| | | | | |
|---|---|---|---|---|
| | | 1301, 1345, 1395, and 1402 | | |
| | | 79, 1395, 263, 1307, J-98, 1301, 1402, 44 265, 23B and 1362 | Considered promising and contained <1 egg/mass plant | Jotwani 1978 |
| 12. | R. dominica | Chady | Less dasmaged compared to RSK | Singhvi and Misra 1979 |
| 13. | A. biseta | Nanshanghang (S. italica) | Most resistant among 1585 lines tested | Cheng et al. 1983 |
| 14. | A. approximata | JFB 801 AND JFB 812 | Less susceptible | Pandey et al. 1985 |
| 15. | A. miliaceae | PR 353, PR 356 AP, PR 359 AP, and PR 457 | Less damaged | Shirole et al. 1982 |
| 16. | S. simplex | A Nos 6, 10, 12, 21p, 22, 44, 48, 221, 227, 232, 278 Bulk, 291 and 296 | No incidence | Sandhu et al. 1977 |
| 17. | H. zea | Tif 23 S | Ovipositional nonpreference due absence of pubescence of foliage | Burton et al. 1977<br>Leuck et al. 1977 |
| 18. | Masalia sp | Ex-Bornu and Souna 3 | Cereal type lines with optimum floral density are more susceptible | Vercambre 1976, 1978 |
| 19. | Raghuva spp | Ex-Bornu and Souna 3 | | Vercambre 1976, 1978 |
| | | Souna, 314 HK 78, ICMS 7819, ICMS 7838, IBV 8001, H 24-38, Nigerian composite, HKB Tif., CIVT, HKP, Zongo, Nieluvs, Boudouma, IBMV 8302, INMG 52, INMV 5001, SRM - Dori, P3 Kolo, ITV 8001, Kassblaga, Yoiumee-Niai, Tars Yombo | Resistant | Ndoye et al. 1986 |
| 20. | Thrips sp | SAR 1805, P 3, NCP 115003, ICI 7530, ICMS 7703 and B 7104 | <10 Thrips/earhead compared to >50 thrips/ head im SAR 116. Compact headed genotypes were generally less damaged | Sharma and Davies 1982 |
| 21. | Birds | IP Nos 146, 88955, 207, 88964, 88974, 88990, 88991, 1668, 6161, RSK, and 23 D2 A x D 356 | Suffered <30% damage<br><10% damage | AICMIP 1972<br>Beri et al. 1969 |
| | | RSK | Hybrid bajra suffered more damage | Jain and Ishwar Prakash 1974 |
| 22. | O. indicus | SAR 849, P 285, P 1430, E 10, and | Resistant | Sharma and Davies 1982 |

Table 6. Insect and mite pests of stored millets

| S.no. | Common name | Scientific name | Nature of damage | Distribution | Reference |
|---|---|---|---|---|---|
| 1. | Lesser grain borer | Coleoptera:Bostrichidae<br>*Rhyzopertha dominicas* Fab. | Destroys the whole grain | Cosmopolitan | Rachie and Majmudar 1980; Singhvi and Misra 1979; Gahukar 1984 |
| 2. | Rusty flour bettle | Coleoptera:Cucujidae<br>*Cryptolestes ferrugineus* Step. | "<br>(Recorded on *P. miliaceum*) | Canada | Singh 1972 |
| 3. | Rice weevil | Coleoptera:Curculionidae<br>*Sitophilus oryzae* Lin. | Feed on the whole grain and reduce it to powder | Cosmopolitan | Oxley 1950; Kamal and Zewar 1973; Rachie and Majmudar 1980 |
| 4. | Maize weevil | *S. zeamais* Mots. | " | America | Meagher et al. 1982 |
| 5. | Khapra beetle | Coleoptera:Dermestidae<br>*Trogoderma granarium* Evert. | " | India<br>West Africa | Pringle 1976; Gahukar 1984 |
| 6. | Mercent beetle | Coleoptera:Silvanidae<br>*Oryzaephilus mercator* Faust. | "<br>(Also recorded on *P. miliaceum* | Cosmopolitan | Sinha 1972; Reddy and Davies 1979 |
| 7. | Saw-toothed beetle | *O. surinamesis* Linn. | "<br>(Also recorded on *P. miliaceum*) | " | Singh 1972; Reddy and Davies 1979; Gahukar 1984 |
| 8. | Red flour beetle | Coleoptera:Tenebrionidae<br>*Tribolium castaneum* Herbst. | Feed on cracked and whole grain | " | Reddy and Davies 1979; Meagher et al. 1982; Gahukar 1984 |
| 9. | Confused flour beetle | *T. confusum* Sacq. | "<br>(Also recorded on *P. miliaceum* | " | Sinha 1972; Reddy and Davies 1979; Gahukar 1984 |
| 10. | Embiid | Embioptera:Embiidae<br>*Oligotoma humbertiana* Saus. | Feed on whole grain | India | Asaf Ali and Subramaniam 1973 |
| 11. | Angoumois grain moth | Lepidoptera:Gelechiidae<br>*Sitotroga cerealella* Oliv. | Feed on cracked and whole grain | Cosmopolitan | Nair 1975; Reddy and Davies 1979; Gahukar 1984 |
| 12. | Rice moth | Lepidoptera:Pyralidae<br>*Corcyra cephalonica* Staint. | | " | Reddy and Davies 1979; Gahukar, 1984 |
| 13. | Almond moth | *Ephestia cautella* Hb. | " | " | AICMIP 1967; Gahukar 1984 |

| | | | | | |
|---|---|---|---|---|---|
| 14. | Indian meal moth | *Plodia interpunctella* Hb. | | " | Reddy and Davies 1979 |
| 15. | -- | *Pyralis manihotalis* Guen. | (Recorded on *E. coracana*) | India | Govindan et al. 1977 |
| 16. | Mite | Acarina:Tyroglyphidae<br>*Acarus siro* Linn. | Feed on the damaged and cracked grain | India | Reddy and Davies 1979 |

Table 7. Bird pests of millets

| S.No. | Common name | Scientific name | Nature of damage | Distribution | Reference |
|---|---|---|---|---|---|
| | | Columbiformes:Columbidae | | | |
| 1. | Blue rock pigeon | *Columba livia* Gme. | Eat grain in the field and stacks | India | Toor and Ramzan 1974 Bhatnagar et al. 1982b |
| 2. | Dove | *Streptopelia decaocto decaocto* Fr. | " | India | Mehrotra and Bhatnagar 1979 |
| 3 | Dove | *Streptopelia decaocto arabica* Neum. | " | Sudan India | Schmutterer 1969; Bhatnagar et al. 1982b |
| 4. | Dove | *Streptopelia decaocto roseogrisea* Sund. | " | Sudan | Schmutterer 1969 |
| 5. | Mourning dove | *Streptopelia decipiens decipiens* Fisch. | " | West Africa | Schmutterer 1969 |
| 6. | Dove | *Streptopelia roseogriseus* | " | Sudan | Schmutterer 1969 |
| 7. | Dove | *Streptopelia turtur isabellina* Bp. | " | Senegal | Bruggers and Ruelle 1981 |
| 8. | Dove | *Streptopelia turtur turtur* Linn. | | Sudan | Schmutterer 1969 |
| 9. | Vinaceous dove | *Streptopelia vinacea* Gme. | " | Nigeria Burkina Faso | Anon. 1977b; Manikowski 1984 |
| 10. | Laughing dove | *Stigmatopelia senegalensis senegalensis* Linn. | " | Sudan Senegal | Anon. 1977b; Funmilayo and Akande 1979; Schmutterer 1969; Bruggers and Ruelle 1981; Funmilayo 1980 |
| | | Passeriformes:Corvidae | | | |
| 11. | Pied crow | *Corvus albus* Mull. | " | Sudan | Schmutterer 1969 |
| 12. | Crow | *Corvus splendens* Veillot | " | India | Mehta and Verma 1968 Bhatnagar et al. 1982b |
| | | Passeriformes:Emberizidae | | | |
| 13. | Black headed bunting | *Emberiza melanocephala* Scop. | " | India | Puttarudriah 1967 |
| | | Passerifermes:Fringilidae | | | |
| 14. | Yellow-fronted canany | *Serinus mozambicus* Muller | " | Nigeria Chad | Anon. 1977b; Das Camara-Smeets 1977; Manikowski 1984 |
| | | Passeriformes:Estrildidae | | | |

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|---|---|---|---|---|---|
| 15. | Cut throat finch | <u>Amadina</u> <u>fasciata</u> <u>fasciata</u> Gmel. | | Sudan | Bruggers and Ruelle 1981; Schmutterer 1969 |
| | | Passeriformes:Phasianidae | | | |
| 16. | Grey breated helment guinea fowl | <u>Numida</u> <u>mileageis</u> Linn. | " | Mali | Manikowski 1984 |
| | | Passeriformes:Ploceidae | | | |
| 17. | Sparrow | <u>Auripasser</u> <u>luteus</u> Litch. | " | Sudan | Bruggers and Ruelle 1981; Schmutterer 1969 |
| 18. | Bufallo weaver | <u>Bubalornis</u> <u>albirostris</u> Viellot | " | Senegal | Bruggers 1979; Manikowski 1984 |
| 19. | Napolean bishop | <u>Euplectes</u> <u>afer</u> Gme. | " | West Africa | Morel 1962; Anon. 1977b; Bruggers and Ruella 1981 |
| 20. | Red bishop | <u>Euplectes</u> <u>orix</u> <u>franciscanus</u> Is. | | Africa | Schmutterer 1969; Anon. 1977b: Elliot 1979; Bruggers 1980; Bruggers and Ruelle 1981 |
| 21. | Bronze Mannikin | <u>Lanchura</u> <u>cucullata</u> Huegl. | " | Senegal Nigeria | Funmilayo and Akande 1979; Funmilayo 1980; Bruggers and Ruelle 1981 |
| 22. | White throated myna | <u>Lonchura</u> <u>malabrica</u> Linn. | " | India Senegal | AICMIP 1971; Bruggers and Ruelle 1981; Manikowski 1984 |
| 23. | Black throated myna | <u>Lonchura</u> <u>malacca</u> Linn. | " | India | AICMIP 1971 |
| 24. | Spotted munia | <u>Lonchura</u> <u>punctulata</u> Linn. | " | India | AICMIP 1971; Bhatnagar et al. 1982b |
| 25. | House sparrow | <u>Passer</u> <u>demesticus</u> Linn. | " | Cosmopolitan | Beri et al. 1969; Toor and Ramzan 1974 |
| 26. | House sparrow | <u>Passer</u> <u>domesticus</u> <u>arboreus</u> Bp. | " | Sudan | Schmutterer 1969 |
| 27. | Grey headed sparrow | <u>Passer</u> <u>griseus</u> Viell. | " | Senegal Sudan | Schmutterer 1969; Da Camara-Smeets 1977; Bruggers 1979; Bruggers and Ruelle 1981 |
| 28. | Eastern spanish sparrow | <u>Passer</u> <u>hispaniolensis</u> <u>transcaspices</u> Temm. | " | India | Mehta and Verma 1968 |
| 29. | Golden sparrow | <u>Passer</u> <u>luteus</u> Licht. | " | West Africa | Das Canara-Smeets 1977; Bruggers and Ruelle 1981; Manikowski 1984 |
| 30. | | <u>Passer</u> <u>motitensis</u> <u>cardofanicus</u> Heugl. | " | Sudan | Scmutterer 1969 |

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|---|---|---|---|---|---|
| 31. | Yellow throated sparrow | *Petronia xanthocollis* Burton | " | India | AICMIP 1971 |
| 32. | Black headed weaver | *Ploceus capitalis dimidiatus* Salv. | " | Africa | Schmutterer 1969 |
| 33. | Village weaver | *Ploceus cucullattus* Muller | " | Africa | Bruggers 1980; Anon. 1977b; Da Camara-Smeets 1977; Bruggers and Ruelle 1981; Manikowski 1984, |
| 34. | Ruppell's weaver | *Ploceus galbula* Rupp. | " | Sudan<br>Somalia | Schmutterer 1969; Bruggers 1980 |
| 35. | -- | *Ploceus luteolus luteolus* Licht | | Sudan | Schmutterer 1969 |
| 36 | Black headed weaver | *Ploceus melanocephalus* Linn. | " | West Afria | Morel 1962; Da Camara-Smeets 1977; Elliot 1979; Bruggers and Ruelle 1981; Manikowski 1984 |
| 37. | Baya | *Ploceus philippinus* Linn. | " | India | AICMIP 1971 |
| 38. | | *Ploceus taeniopterus furensis* Lin. | | Sudan | Schmutterer 1969 |
| 39. | | *Ploceus vitellinus vitellinus* Licht. | | Sudan | Schmutterer 1969 |
| 40. | Vitelline marked weaver | *Ploceus velatus* Viellot | | Senegal<br>Mali | Manikowski 1984 |
| 41. | Red headed quelea | *Quelea erythropes* Hart. | " | Africa | Pradat 1963; Elliot 1977; Funmilayo and Akande 1979; Funmilayo 1980; Rachie and Majmudar 1980; Bruggers 1979, 1980; Bruggers and Ruelle 1981; Manikowski 1984 |
| 42. | Red billed quelea | *Quelea quelea aethiopica* Sund. | " | Africa | Schmutterer 1969; Rachie and Majumdar 1980 |
| 43.. | Quelea | *Quelea quelea centralis* Van Someren | " | Somalia | Bruggers 1980 |
| 44. | Quelea | *Quelea quelea quelea* Linn. | " | Africa | Pradat 1963; Anon. 1977b; Da Camara-Smeets 1977; Elliot 1977; Funmilayo 1980 and Akande 1979; Funmilayo 1980; Manikowski 1984 |
| 45. | | *Sporopipes frontalis frontalis* Daud. | " | Sudan | Schmutterer 1969 |
| 46. | | *Sporopipes frontalis emini* Neum. | | Sudan | Schmutterer 1969 |

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| | | Passeriformes:Sturnidae | | | |
| 47. | Myna | Acridotheres tristis Linn. | " | India | Toor and Ramzan 1974 |
| 48. | Blue eared glossy starling | Lamprotornis chalybeus Hem. and Ehr. | " | Africa | Schmutterer 1969; Anon. 1977b; Da Camara-Smeets 1977; Bruggers 1979; Manikowski 1984 |
| 49. | Chestnut-bellied starling | Spreo pulcher Muller | " | Somalia<br>Senegal | Bruggers 1980<br>Manikowski 1984 |
| 50. | Rosy pastor | Sturnus roseus Linn. | " | India | Mehrotra and Bhatnagar 1979 |
| 51. | -- | Sturnus vulgaris Linn. | " | India | Mehrota and Bhatnagar 1979 |
| 52. | Yellow billed parrot | Poicephalus senegalus Linn. | " | Senegal | Bruggers and Ruelle 1981 |
| 53. | Parakeet | Psitacula cyanocephala Linn. | " | India | AICMIP 1971 |
| 54. | Long tailed parakeet | Psitacula krameri Scop. | " | West Africa<br>India | Beri et al. 1969<br>Toor and Ramzan 1974; Bruggers 1979; Bruggers and Ruelle 1981 |
| | | Struthioniformes:Struthionidae | | | |
| 55. | Ostrich | Struthio camelus camelus Linn. | | Sudan | Schmutterer 1969 |

Table 8. Rats and mice damaging millets in field and stores

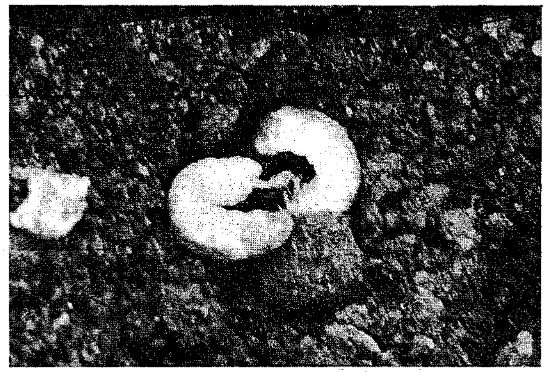
| S.No. | Common name | Scientific name | Nature of damage | Distribution | Reference |
|---|---|---|---|---|---|
| | | Rodentia:Cricetidae | | | |
| 1. | Gerbil | Gerbillus pyramidum Geoff. | Feed on cereal grains in the field | Senegal | Hopf et al. 1976 |
| 2. | Indian Gerbil | Gerbillus nanus indus Thom. | " | India | Hopf et al. 1976 |
| 3. | Desert rat | Meriones hurianeae Jerd. | " | South Asia | Prakash and Ghosh, 1975; Hopf et al. 1976 |
| 4. | | Tatera guineae Thom. | " | Senegal | Hopf et al. 1976 |
| 5. | | Tatera indica Hard. | " (Also feed on grain in the stores) | South Asia | Prakash and Ghosh 1975; Hopf et al. 1976 |
| 6. | | Tatera kempi Wrg. | " | Senegal | Hopf et al. 1976 |
| | | Rodentia:Muridae | | | |
| 7. | Nile rat | Arvicanthus niloticus Desm. | " (Also feed on grain in the stores) | Ethiopia, Sudan Central Africa | Schmutterer 1969; Hopf et al. 1976 |
| 8. | Field rat | Bandicota bengalensis Gray | " | South Asia | Hopf et al. 1976 |
| 9. | Field rat | Bandicota indica Bech. | " | India | Mehta and Verma 1968 |
| 10. | | Golunda spp | " | South Asia | Hopf et al. 1976 |
| 11. | Giant rat | Cricetomys gambianus Wat. | " | Africa | Rachie and Majmudar 1980 |
| 12. | | Lemniscomys spp | " (Also feed on the grain in the stores) | East Africa | Hopf et al. 1976 |
| 13. | | Mastomys coucha A. Smith | " | Senegal | Hopf et al. 1976 |
| 14. | Multimammate rat | Mastomys natalensis A. Smith | " (Also feed on grain in the stores) | Africa | Schmutterer 1969; Hopf et al. 1976 |
| 15. | | Mastomys sp | " (Also feed on the grains in the stores) | Mauritania, Central Africa | Hopf et al. 1976 |
| 16. | | Mus booduga Gray | " | South Asia | Hopf et al. 1976 |
| 17. | Pigmey mouse | Mus minutoides A. Smith | " | Central | Hopf et al. 1976; |

| | | | | | |
|---|---|---|---|---|---|
| | | | | Africa | Rachie and Majmudar 1980 |
| 18. | Common mouse | Mus musculus Linn. | Feed on the grains in the stores | India | Mehta and Verma 1968; Hopf et al. 1976 |
| 19. | | Mus sp | " | Central Africa | Hopf et al. 1976 |
| 20. | | Otomys sp | Feed on cereal grains in the field | East Africa | Hopf et al. 1976 |
| 21. | Field rat | Nesokia indica Gray | " | South Asia | Mehta and Verma 1968; Hopf et al. 1976 |
| 22. | | Rattus meltada pallidior Ryley | " | India | Prakash and Ghosh 1975 |
| 23. | Brown rat | Rattus norvegicus Berk | " (Also feed on grain in the stores) | Africa Asia | Hopf et al. 1976 |
| 24. | Common rat | Rattus rattus Linn. | " (Also feed on grain in the stores) | Africa South Asia | Puttaradriah 1967; Hopf et al. 1976 |
| 25. | | Rattus spp | " | South Asia | Hopf et al. 1976 |

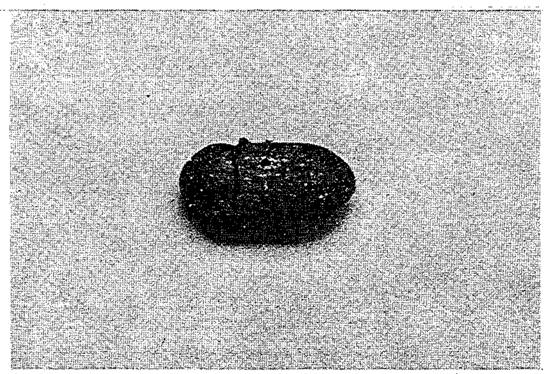
# LIST OF PLATES

1. *Plants showing stunting in the front row and dying due to white grub damage (*Holotrichia *sp).*

2. *White grub larvae in the soil.*



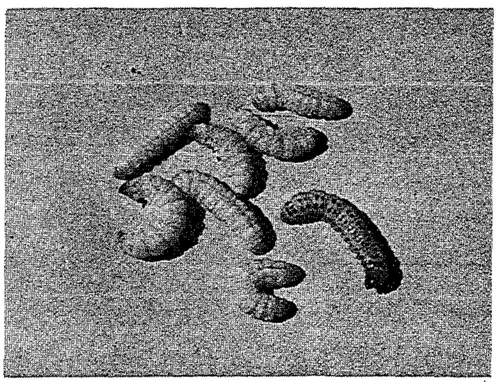
3. *Seedlings damaged by wireworm larva (*Gonocephalum *sp).*



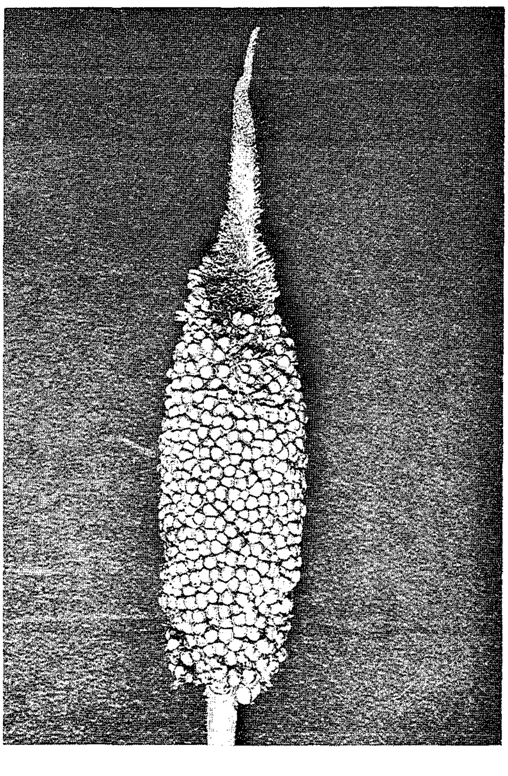
4. *Wireworm adult.*

*5. Leaf damage by pearl millet shoot fly (*Atherigona approximata*).*

*7. Dead heart produced by African millet stem borer (*Acigona ignefusalis*).*

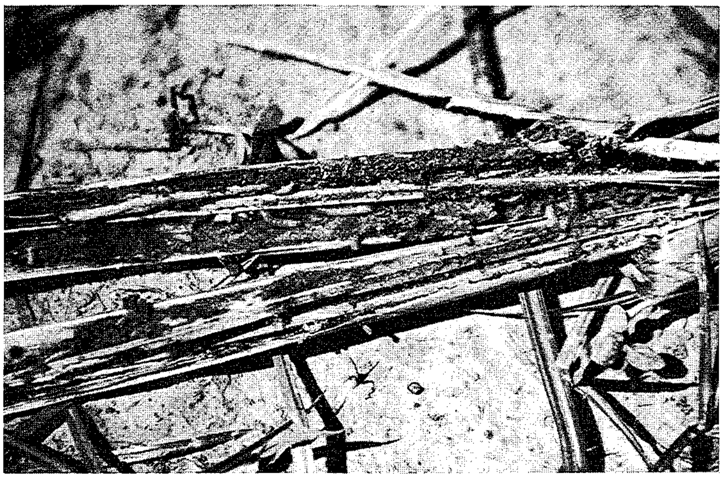


*8. Diapausing (nonpigmented) and nondiapausing (pigmented) larvae of the African stem borer (*Acigona ignefusalis*).*

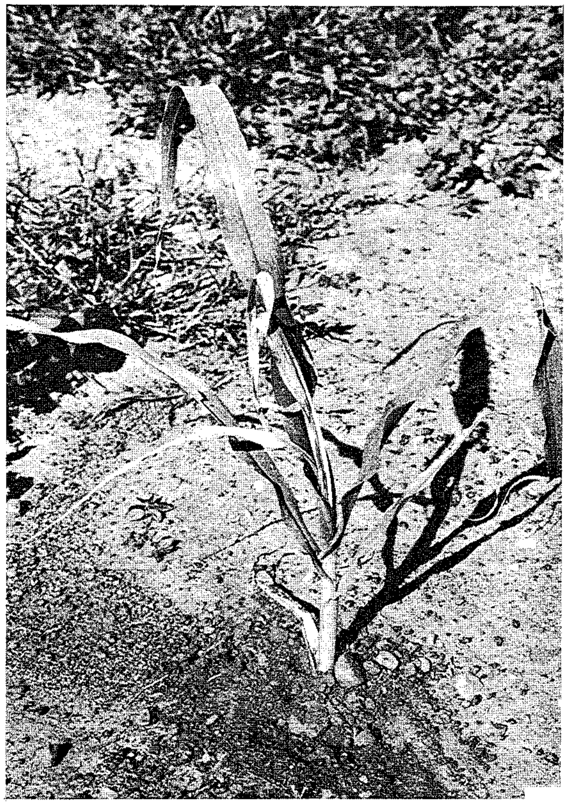


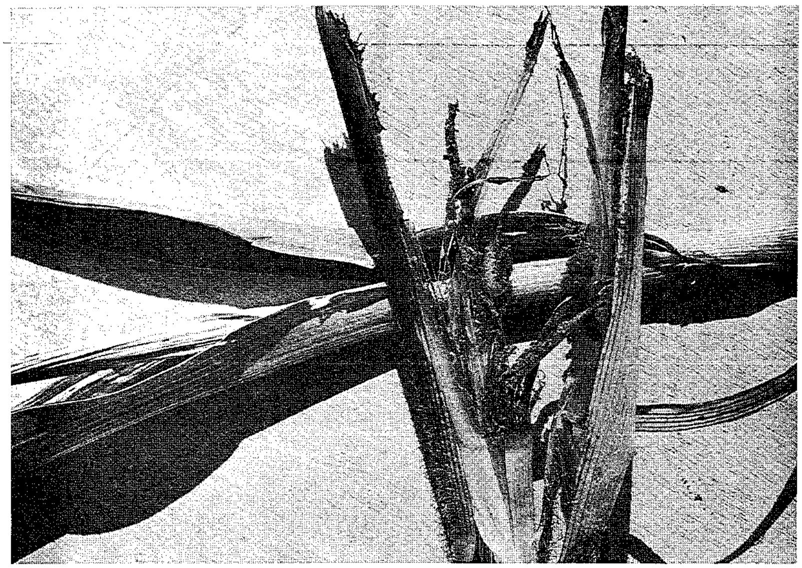
*6. Earhead damaged by pearl millet shoot fly.*

*9. Stem tunneling by the African millet stem borer (*Acigona ignefusalis*).*



*10. Deadheart produced by the spotted stem borer (*Chilo partellus*).*



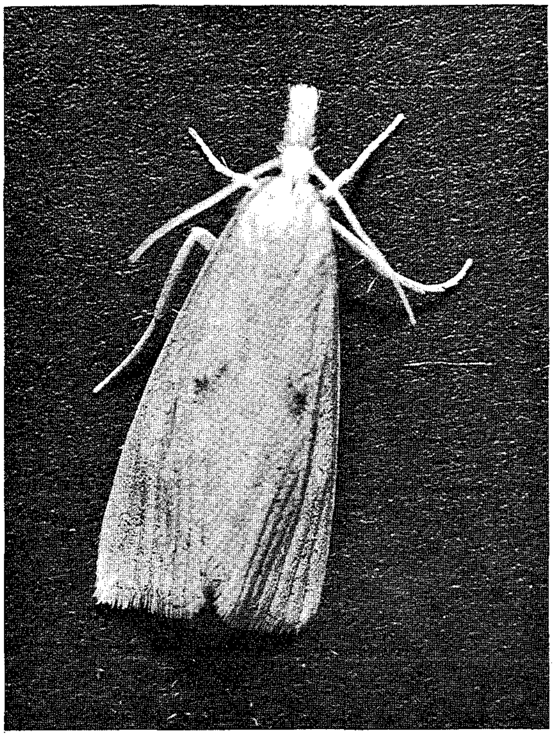


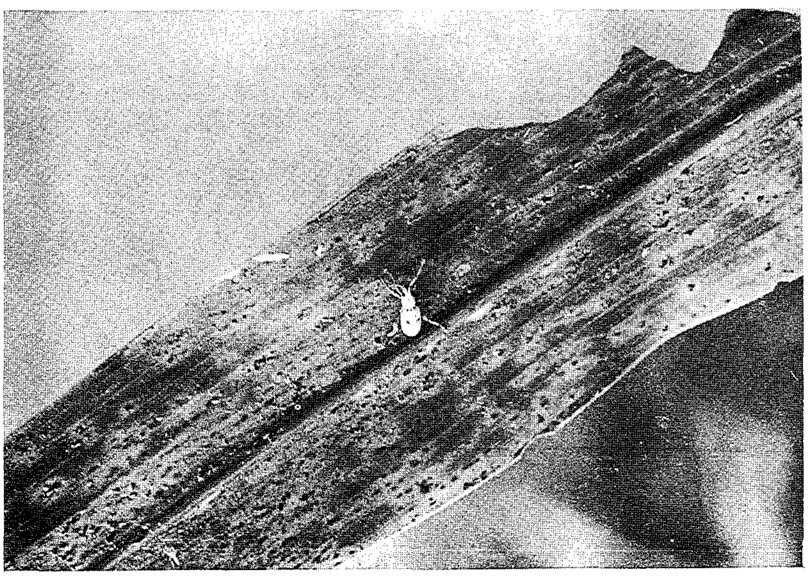
*11. Stem damaged by the spotted stem borer.*

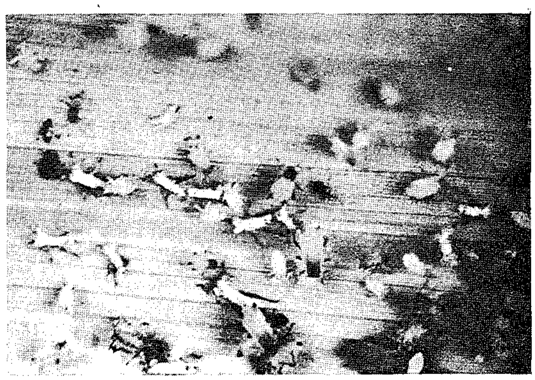
*12. Spotted stem borer larva.*

14. *Seedlings damaged by grubs of the grey weevil (*Myilocerus *sp).*

13. *Spotted stem borer adult.*





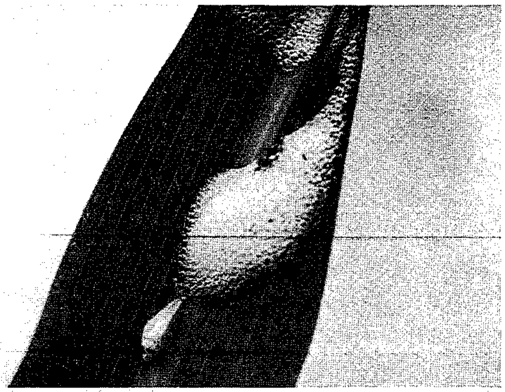


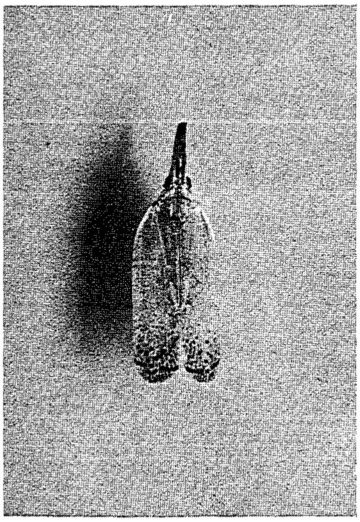
16. *Corn leaf aphids (*Rhopalosiphum maidis*).*

15. *Leaf damaged by grey weevil adults.*

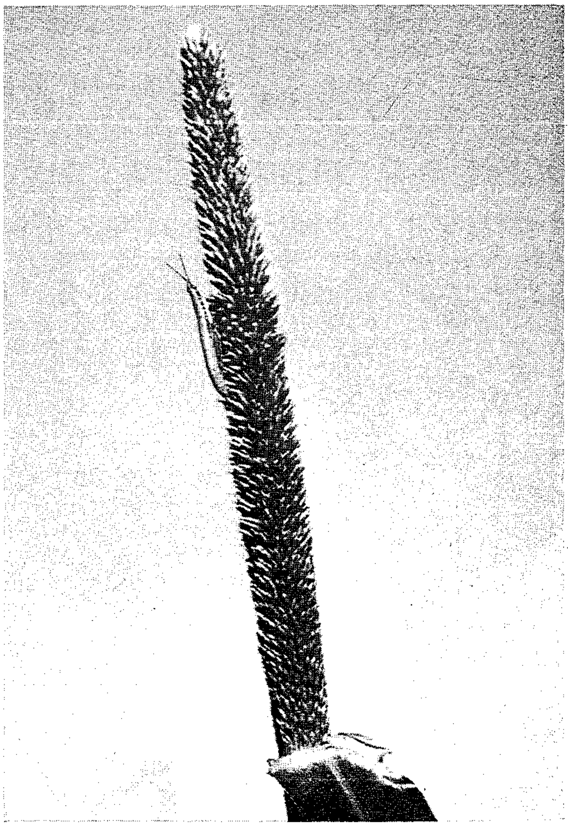
*18. Leaves damaged by the shoot bug (*Peregrinus maidis*).*

*17. Spittle bug (*Poophilus costalis*) feeding on a leaf.*



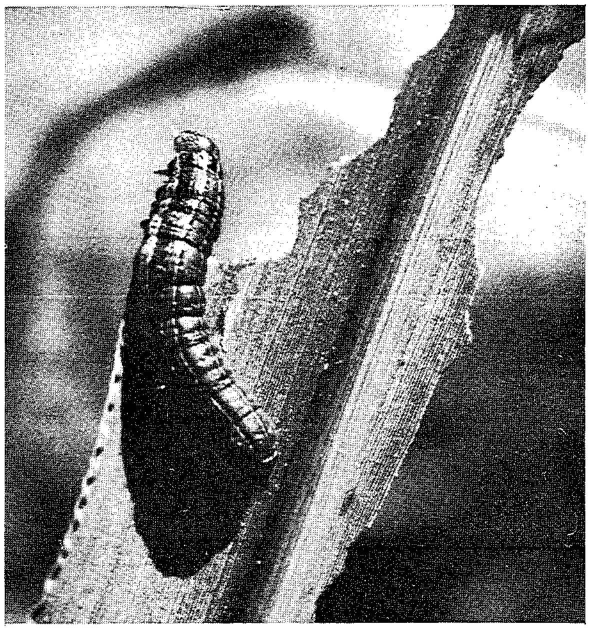


*19. Sugarcane pyrilla (*Pyrilla perpusilla*).*

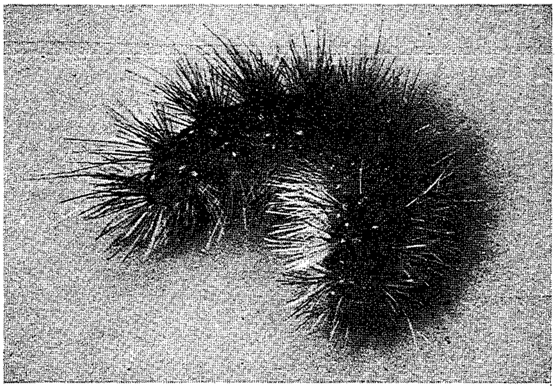


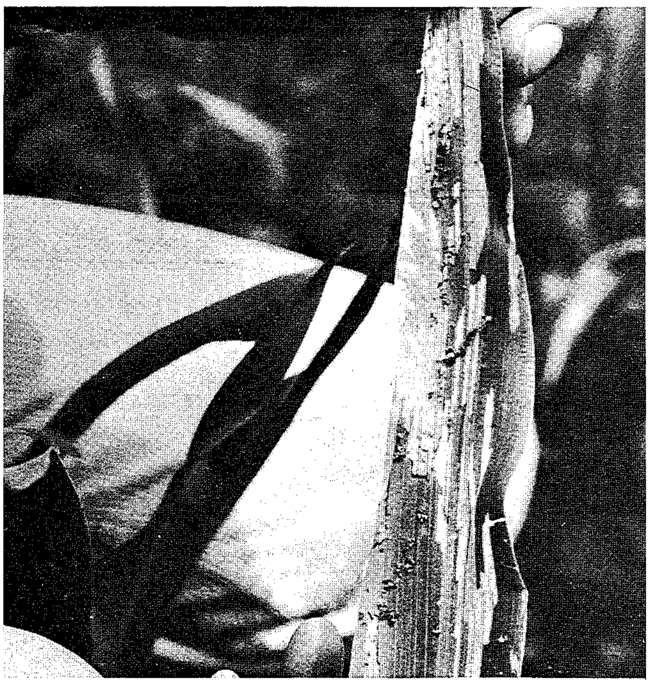
*20. Deccan wingless grasshopper feeding on a pearl millet head (*Colemania sphenarioides*).*

*22. Armyworm larva feeding on a pearl millet leaf.*

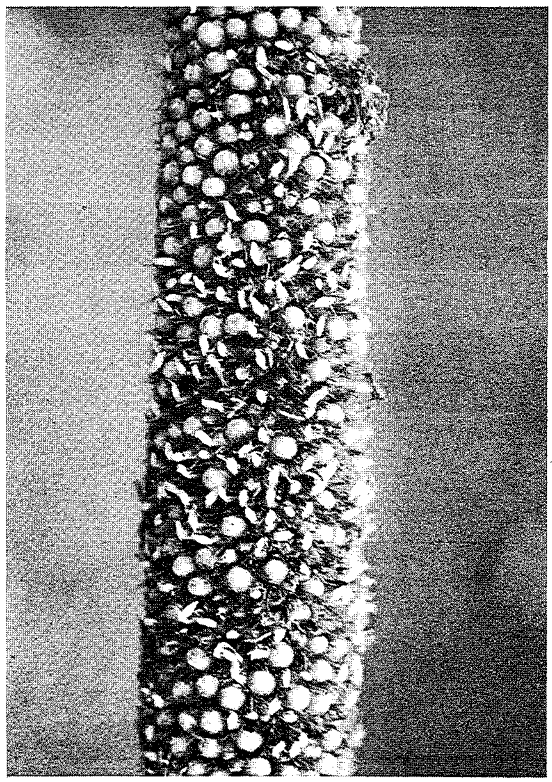


*21. Red hairy caterpillar (*Amsacta moorei*).*



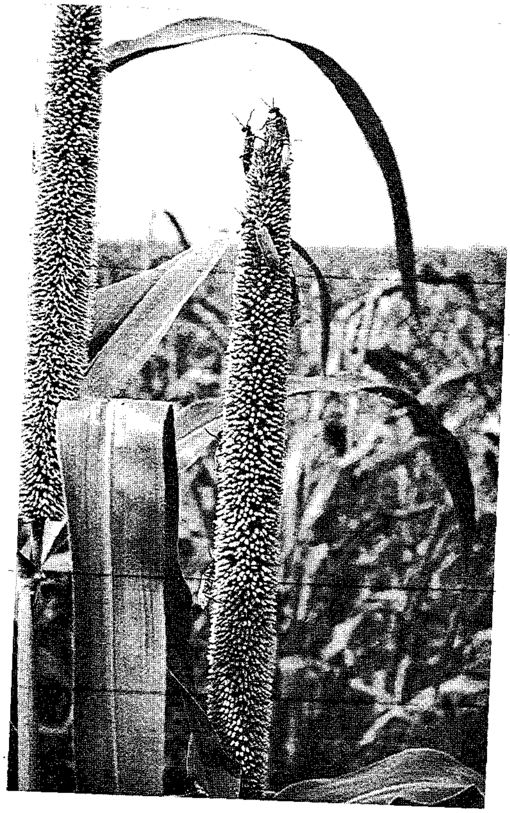


*23. Leaf damaged by the leaf roller (*Marasmia trapezalis*).*

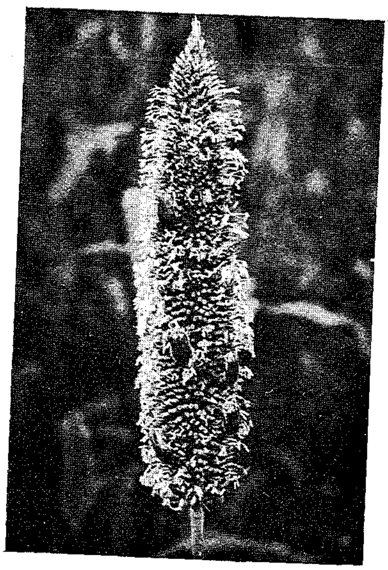


*24. Earhead damaged by the millet midge (*Geromyia penniseti*) (pupal cases are hanging from the glumes).*

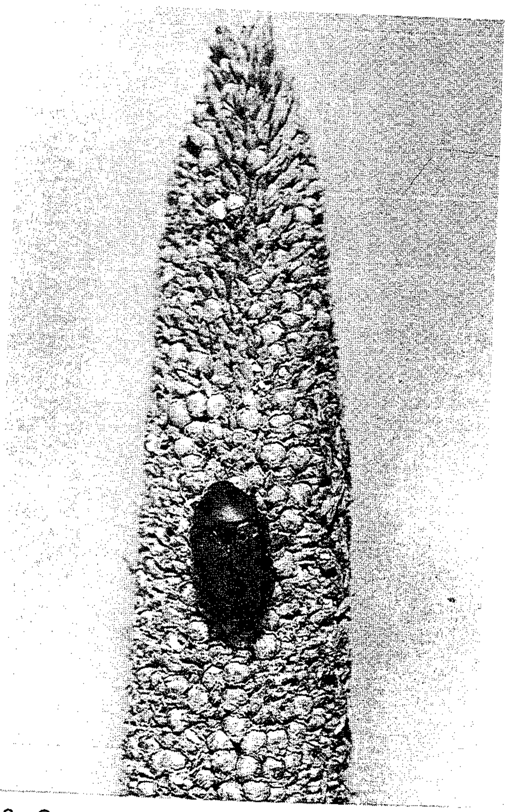
25. *Blister beetles (*Cylindrothorax tenuicollis*) feeding on a pearl millet inflorescence.*



26. *Blister beetle (*Mylabris pustulata*).*

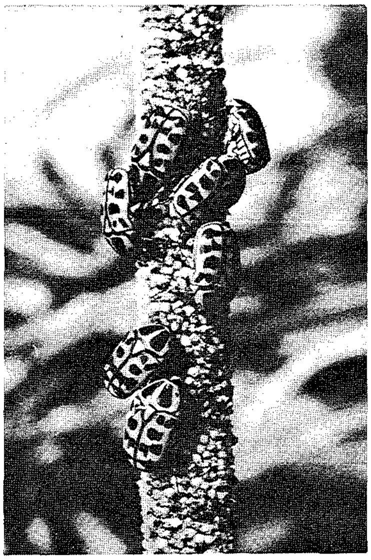


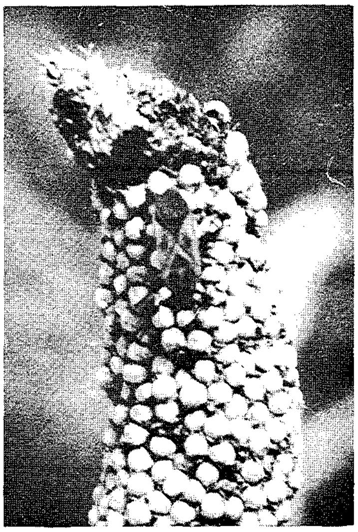
27. *Chafer beetles (*Chiloloba acuta*) feeding on a pearl millet inflorescence.*



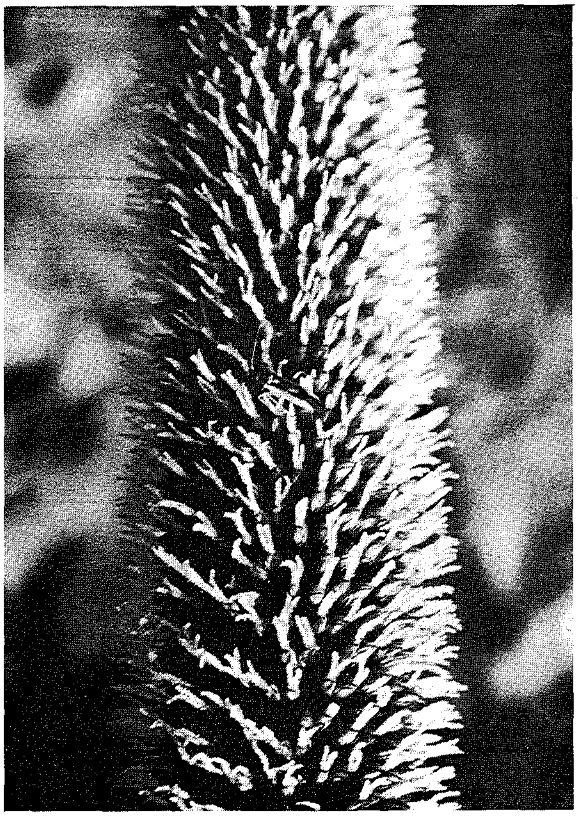
28. *Scarabaeid beetle (*Oxycetonia versicolor*) feeding on pearl millet grain.*

29. *African chafer beetle (*Pachnoda *sp) adults feeding on a pearl millet panicle.*

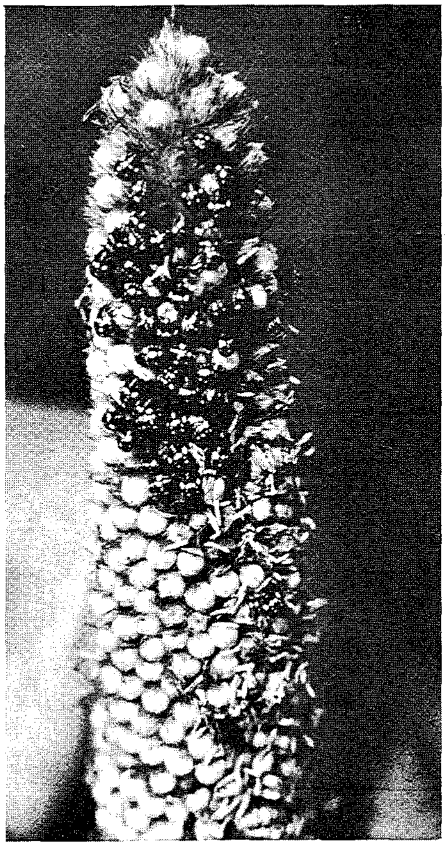




30. *Milkweed bug (*Spilostethus *sp) feeding on pearl millet grain.*

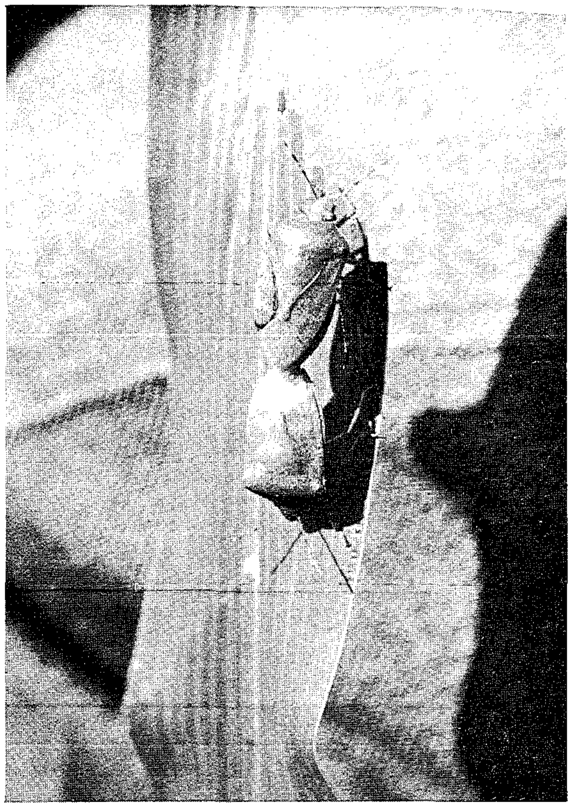


31. *Sorghum head bug (*Calocoris angustatus*) feeding on a pearl millet panicle.*

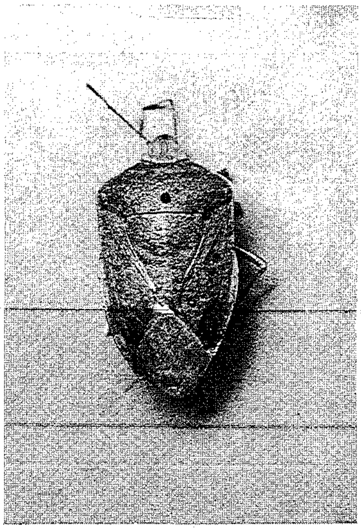


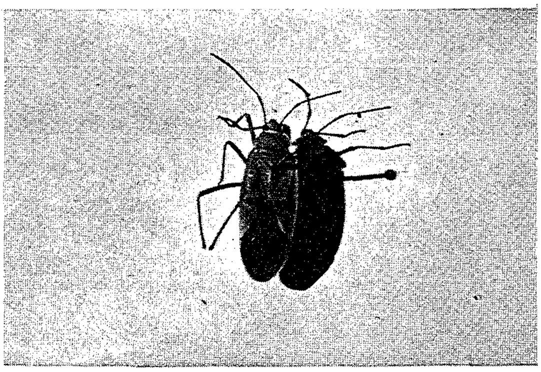
32. *Painted bug (*Bagrada cruciferarum*) nymphs feeding on a pearl millet panicle.*

*34. Green stink bug (*Nezara viridula*).*

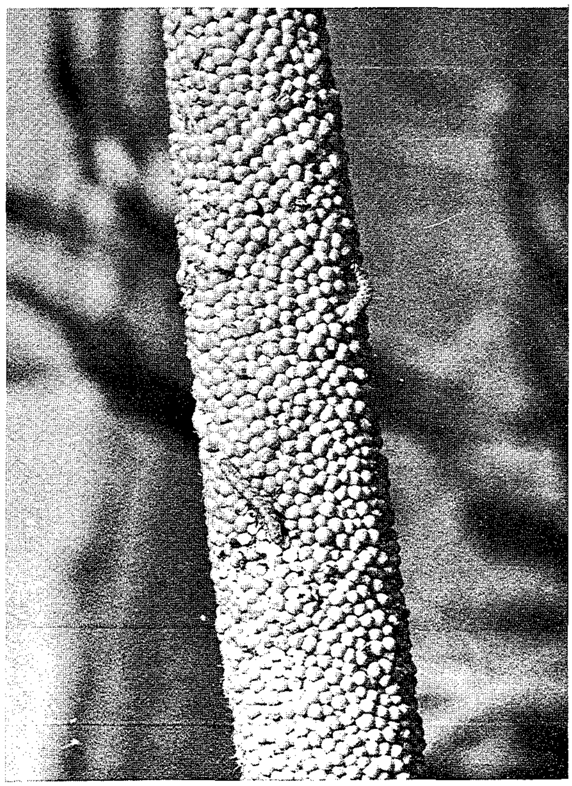


*33. Stink bug (*Agonoscelis pubescens*).*



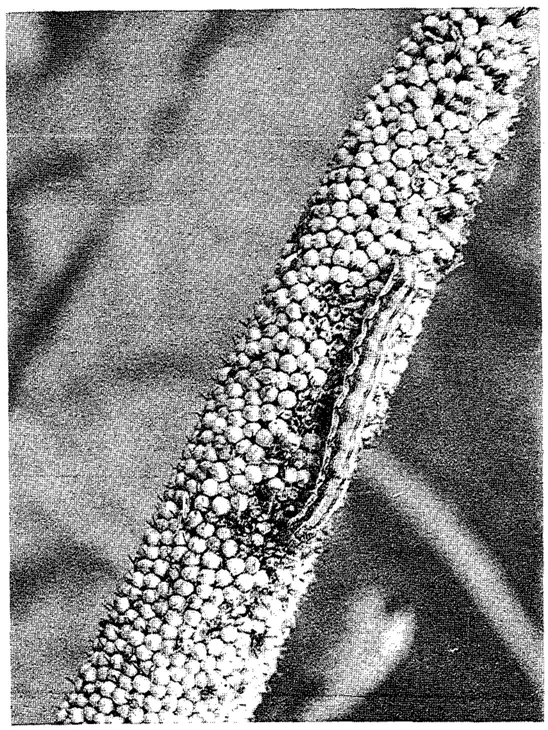


*35. Red cotton bug (*Dysdercus superstitiosus*).*



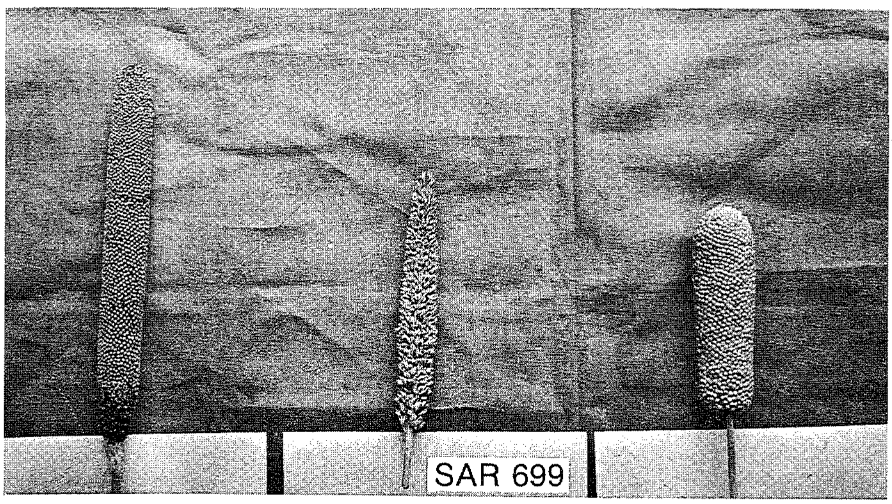
*36. Larva of the head caterpillar (*Eublema silicula*) feeding on pearl millet grain.*

37. *Earhead damaged by the larvae of* Heliothis armigera.



38. *Larva of* Heliothis armigera *feeding on pearl millet grain.*

39. *Earheads damaged by the head caterpillar (*Raghuva albipunctella*).*




40. *Earhead of SAR 699 badly damaged by thrips (*Thrips *sp).*

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