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INSECT PESTS OF SORGHUM AND THEIR CONTROL*

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ABSTRACT

The insect pests that attack sorghum (*Sorghum bicolor*) are discussed in this paper Crop damage is evaluated in relation to pest species, and plant part or crop stage where infestations occur, namely, seedling, foliage, stem and panicle The importance of major pest species is discussed on a regional basis shoot fly (*Athengona soccata*), stem borers, sorghum midge (*Contarinia sorghicola*) and head bugs in Africa and India, greenbug (*Schizaphis graminum*) and sorghum midge in the USA, sorghum midge, armyworms and greenbug in Central and South America, and sorghum midge and *Heliothis* in Australia A brief account of current control measures is given for each insect pest across regions, and contrasting differences between those in the developed and developing countries However, a more holistic pest management approach is necessary in all pest control situations and host plant resistance is regarded as the major component for mounting successful control strategies

INTRODUCTION

Sorghum (*Sorghum bicolor*) is a major food source for man and animals in many countries An estimated 48 million ha was grown to sorghum in 1982 throughout the world (FAO, 1983) Of this area, 15 million ha was grown in Africa and 16 million ha in India, where sorghum is an important cereal crop and an essential component in the caloric requirement of the people When compared with other cereal crops such as rice, wheat and maize, however, the average sorghum yield of 1179 kg/ha is low (House, 1985) This is because sorghum is mostly grown in hot and dry conditions where its yield capacity is greatly restrained

Insect pest is one of the major constraints to sorghum production Numerous insect and mite species attack the plant soon after the seed is sown until long after the grain is harvested A wealth of information on the arthropod pests associated with sorghum has been continuously updated and abundant lists of pest species as well as their parasites and predators are available (Sharma, 1985 Seshu Reddy and Davies, 1978, 1979 Teetes et al, 1983) In this paper, we focused on the species that persistently cause serious economic damage in various geographical areas of the world It does not present an exhaustive list of sorghum herbivores, but emphasizes the major insect pests in terms of their distribution, mode of damage and current control measures Major mite species are included, but stored product insects are not discussed

The economic importance and severity of damage for some species may vary within their geographical distribution *Contarinia sorghicola* the sorghum midge, for example, is distributed worldwide but its economic importance varies depending on the region The severity of midge infestation seems to be related to high humidity and warm climate In India, sorghum midge is most serious in the southern state of Karnataka, while in West Africa, severe losses have been reported in Nigeria, Mali and Burkina Faso It is a major pest in southern USA and the neighboring areas of Mexico In Central America, only the coastal areas are affected *Schizaphis graminum*, the greenbug, and *Celama sorghiella*, the sorghum webworm, are major pests both in the continental USA and throughout Latin America, but these species are of minor importance in Africa, Asia and Australia *Athengona soccata*, the sorghum shoot fly, is a serious pest in Africa, Southeast Asia and India, but is not found in the Americas and Australia *Heliothis armigera* is a key pest in India and Australia, but in Thailand, this species causes only occasional damage to sorghum although it is an important pest in cotton in this country *Chilo partellus* the spotted stem borer, is widely distributed in East Africa and is an economically important pest, while it is not a serious pest in West Africa The species is also present in the Indian subcontinent, causing severe damage especially in the north and central parts *Elasmopalpus lignosellus*, the lesser cornstalk borer, is regarded as one of the most serious pests of sorghum in the southeastern USA In the western part of the country, however, the species is not of much importance

Table 1 summarizes the world occurrence of economically important sorghum pests The species are grouped by the plant parts that they attack, although in some cases, feeding activity is not limited to a particular sorghum plant part

DISTRIBUTION, TYPES OF DAMAGE AND CONTROL METHODS

Table 2 presents the kinds of damage induced by the major insect pest species and the prevalent control measures in respective regions As in Table 1, the species are divided into five groups soil insect pests, seedling pests, foliage feeders, stemborers and panicle feeders They are discussed in detail in the following sections

Soil insect pests

The most serious soil insect pests are the larvae of Scarabaeidae or whitegrubs. Several species are worldwide pests on various crop plants Larvae feed on roots and may kill the seedlings Larger plants may withstand immediate damage, but stunting and lodging may occur In sandy soils in northern India, *Holotrichia serrata* and *Lachnosterna consanguinea* are serious pests on sorghum (Srivastava, 1985) The

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*Submitted as CP No 415 by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) adults are known as May or June Beetles and the species are univoltine. The beetles actively oviposit at night and are attracted to light, thus they can be collected with light traps and be killed. Raodeo et al. (1976) reported that this practice of trapping beetles, common in northern India, adequately controls this pest. Soil treatment with insecticides, such as aldrin and diazinon in dust formulation, can be used to control heavy infestation, but it is less effective than capturing the adult insects.

Among soil-inhabiting insect pests, coleopteran larvae of Elateridae called wireworms, and Tenebrionidae or false wireworms, attack sorghum seeds soon after sowing, usually boring into seeds before germination takes place. Seed treatment with chemicals generally reduces the incidence to an appreciable extent (Teetes et al., 1983).

Seedling pests

Atherigona soccata **(Diptera: Muscidae)**

Many species of shoot fly are found in sorghum in Africa, Asia and Mediterranean Europe, but they do not occur in the Americas and Australia (Srivastava, 1985). Their infestation causes the central shoot of seedlings to wither, hence, the so-called deadheart symptom appears. The muscid larvae cut the growing point of the plant and feed on the decaying tissue, thus emitting a foul smell. Younger plants (10-21 days old) are more susceptible to the attack.

In India, up to 90 percent sorghum seedling infestation has been recorded (Hiremath and Renukarya, 1966; Rao and Gowda, 1967) and yield loss was directly related to infestation level (Rai and Jotwani, 1977). Favorable temperature and higher relative humidity in the rainy season rapidly build up the shoot fly population, leading to severe stand loss. Staggered planting, due to late or poor rainfall, also induces high shoot fly damage. In the African continent, more than 20 species of shoot flies are present and their economic importance varies depending on the region (Nwanze, 1985). *Atherigona soccata, A. marginifolia* and *Acritochaeta orientalis* are common in West Africa.

Extensive studies on shoot fly-resistant varieties have been undertaken in India (Blum, 1972; Soto, 1972; Maiti and Bidinger, 1979; Taneja and Leuschner, 1985a). Morphological characters of the plant were highly correlated with shoot fly resistance (Singh and Jotwani, 1980a). Pale green and shiny leaves, i.e., glossy leaves are not preferred by ovipositing females; leaves with pubescence (short, pointed trichomes) had lower infestation incidence (Soto, 1974; Raina, 1982). Ovipositional nonpreference is apparently the main mechanism of resistance (Blum, 1967; Jotwani et al., 1971a). Antibiosis to larval attack is attributed to such factors as hindrance by leaf trichomes of larval movement, harder leaves (greater silica deposit and cell lignification) and some biochemical deficiencies in leaves (Raina et al., 1981; Raina, 1981; Blum, 1968; Singh and Jotwani, 1980b). Out of 14 000 germplasm lines tested in screening trials, 42 were less susceptible over five seasons at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India (Taneja and Leuschner, 1985a).

Chemical control using carbofuran gave good results in Thailand (Meksongsee and Chawanapong, 1985). Chemical seed treatment against shoot fly also acts as a protectant against grain-feeding weevils, such as *Sitophilus zeamais* and *S. oryzae.* Seed treatment with carbofuran is also practiced.

Time of planting is also crucial. Coordinated early planting in large areas lessens shoot fly infestation.

Foliage feeders

Grasshoppers and locusts (Orthoptera: Acrididae)

Along the border of Thailand and Cambodia, *Patanga succincta,* a grasshopper species, is a major pest of sorghum and is difficult to control (Meksongsee and Chawanapong, 1985). An area of 307 200 ha was severely damaged in 1974 in Thailand (Roffey, 1979). The species is a general feeder (polyphagous). Since the species in all stages consume the foliage, the cumulative effect of the infestation is of great economic importance. Seedlings may be totally destroyed, although more mature plants might recover from attack by producing new leaves or tillers.

In the light of integrated locust pest management in Thailand, Visetsulka et al. (1980) indicated some practical measures against this pest. Grasshoppers are hand-picked, sold or used for food. Grasshoppers infected by a fungus disease *Entomophthora grylli* can be collected and released in other areas to induce the spread of the disease. In mixed-cropping systems (sorghum/groundnut), spraying insecticides (0.2% carbaryl) against the grasshoppers as they sought shelter from high daytime temperatures in groundnut bushes, gave effective control (Visetsulka et al., 1980). Groundnut is a crop that is not attacked by this pest.

Several species of grasshoppers also occur in Africa and can cause severe damage to sorghum and other cultivated Graminae. In the West African Sahel, *Oedaleus senegalensis* and *Aiolopus simulatrix* are the major species. Recent grasshopper outbreaks have been attributed to poor and inadequate monitoring.

Spodoptera frugiperda **(Lepidoptera: Noctuidae)**

Spodoptera frugiperda, commonly known as the fall armyworm, is one of the most economically important pests of food crops in Central America. Its distribution extends to North, Central and South America and to the Caribbean region (CIE, 1985). Other related species of armyworms, *S. armigera, S. litorallis* and *S. exigua,* are found in Africa and Asia but their occurrence and damage are usually sporadic. Most studies on the species have been made with maize, and not much data are available on damage to sorghum (Andrews, 1980).

All plant parts and stages are attacked by the noctuid larvae. Seedlings may be cut at the base. Feeding on tender parts of the whorl leaves results in characteristic rows of holes across the leaves. Tunneling of the stem and feeding on the developing panicle are common (Andrews, 1980). Huezo de Mira and Lainez (1983) evaluated the effect of species on sorghum yield in El Salvador and found that larval damage resulted in 60 percent grain yield loss when the larvae were introduced on younger plants. In older plants, losses ranged from 37 to 41 percent.

Andrews (1980) recommended that the caterpillars be hand-picked and destroyed. He also noted the use of insecticides, such as phoxim, in granular formulation which can be manually (or with simple devices) deposited directly into the whorl. Spray and dust formulations are potentially detrimental to the natural enemies, and the larvae are not effectively exposed to the insecticides.

Although a few evaluation techniques for screening resistant varieties were developed in the USA and by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in collaboration with Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) in Mexico (Wiseman and Gourley, 1982; Guiragossian and Mihm, 1981), research on sorghum resistance to the fall armyworm is limited (Wiseman and Davis, 1979). Open and loose panicle types are less affected, as the larvae are exposed to predacious insects and birds (Doggett et al., 1970).

Mythimna spp. (Lepidoptera: Noctuidae)

Mythimna separata is distributed throughout the South to Far East Asia, India, Australia and New Zealand (Teetes et al., 1983). Infestation is most noticeable in maize and sorghum. The larvae feed on foliage during the night, often leaving only the midrib portion uneaten. Defoliated plants might recover by producing new leaves or tillers, thus grain yield is not often significantly reduced (Meksongsee and Chawanapong, 1985). Although chemical control is effective, treatment is generally not necessary. High level of tolerance in the host plant exists and natural enemy complex usually keeps the pest population in check (Teetes et al., 1983).

Other species of *Mythimna* can be of great economic significance. In the central states of Mexico, *M. unipuncta* has been causing serious damage to the developmental stage of sorghum since the 1970s (Diaz, 1985). The lepidopteran larvae voraciously consume young leaves and their damage reached devastating levels by 1979. Early detection of the species and immediate insecticidal treatment are critical to effectively control the situation (Diaz, 1985).

Schizaphis graminum (Homoptera: Aphididae)

As in any other aphid species, *S. graminum* (greenbug) high infestation during the seedling, young foliage and milk to dough stages of grain causes loss of plant vigor, reddening of leaves and decreased grain yield. The species transmits maize mosaic virus.

Previously regarded as a wheat pest in the USA, this aphid gained major pest status in sorghum during the last 2 decades, especially in the Great Plains (Young and Teetes, 1977). The heavy use of chemicals disrupted the natural enemy complex, particularly of parasitoids. Various biotypes were identified, further upsetting the chemical as well as host-plant resistance control measures (Wood, 1961; Wood et al., 1969; Harvey and Hackerott, 1969a, b). More research emphasizing resistant cultivars, biological control methods, cultural practices and judicious chemical use is advocated for integrated pest management (Pitre, 1985).

The situation in neighboring Mexico is quite different from that in USA. The species outbreak is only recent in Mexico and *S. graminum* is not considered a serious pest. Its incidence is sporadic and localized, and any insecticidal treatment easily controls the greenbug (Diaz, 1985). In the sorghum-growing areas of Brazil, the species is believed to be a potential key pest, as substantial crop damage was reported recently. Efforts on research and development of effective control measures against this potential pest have been initiated (Viana, 1985).

Rhopalosiphum maidis (Homoptera: Aphididae)

This pest species is prevalent worldwide. *Rhopalosiphum maidis* can be found in the tropical and temperate countries in Asia, Africa, Australia, New Zealand and the Americas (CIE, 1971). Colonies of this aphid are typically found deep in the whorl of the middle leaf or undersides of leaves, stems and panicles. The species is known to transmit maize dwarf virus. Heavily infested leaves show yellowish blotches and some necrosis may occur at leaf edges. On the honeydew produced by the aphids, sooty molds or saprophytic fungi may grow. Abundant presence of honeydew may hinder normal grain harvesting procedures due to its stickiness (Teetes et al., 1983).

Infestation of this species rarely affects grain yield, thus any population control measure is seldom justified. Organophosphorous systemic insecticides can be effectively used if necessary. A complex of natural enemies might even be augmented by the presence and abundance of this aphid on sorghum, which would in turn protect other crops in the same area (Teetes et al., 1983).

Oligonychus pratensis (Acarina: Tetranychidae)

Oligonychus pratensis is the only non-insect pest considered of economic importance. It appears to be native to North America and attacks monocotyledons (Young and Teetes, 1977). Another species of the same genus, *O. indicus*, is also a serious sorghum pest in certain parts of India (Shah et al., 1975).

Initial mite infestation can be observed on the underside of the lower functional leaves. Rapid population buildup, which is positively correlated with hot and dry environmental conditions, covers the whole plant with fine webbing and causes the leaves to discolor from healthy green to yellow, red and brown as damage intensifies (Teetes et al., 1983). Natural enemy complex, including predacious mites, has not given satisfactory results. Current control measures against this mite solely depend on chemicals, although mite-resistant sorghum germplasm has been reported in Texas (Young and Teetes, 1977).

Stem borers

Chilo partellus (Lepidoptera: Pyralidae)

Chilo partellus stem borer is a serious sorghum pest throughout India, particularly in the northern and central regions (Jotwani et al., 1971b), and also in the Far East countries, such as Indonesia, Malaysia, Taiwan and Sri Lanka. It is also widely distributed in eastern Africa (Seshu Reddy and Omolo, 1985).

Chilo partellus attacks all parts of the sorghum plant, except the roots. Seedlings may develop the deadheart symptom. Early instar larvae feed on leaves, leaving transparent window-like holes on the whorl leaves. More mature larvae eat through the leaves resulting in a shot-hole appearance across the leaf. Larvae also bore into the stem and cause extensive tunneling. Similar damage to the panicle stalk usually affects grain maturity. Some individuals may remain in stems and stubbles after harvest as diapausing larvae and become a source of infestation in the next growing season (Teetes et al., 1983).

Diverse control methods are practiced against this serious pyralid pest. Host plant resistance is a vital component in stem borer control. By screening numerous sorghum varieties, sources and mechanisms of resistance have been identified (Jotwani et al., 1978; Sharma et al., 1983; Taneja and Leuschner, 1985b). At ICRISAT in India, over 70 stem borer-resistant germplasm sources and breeding lines have been identified and are being used in breeding programs. Resistance is attributed to ovipositional nonpreference and antibiosis mechanisms. When given a choice, gravid females preferred to lay their eggs on susceptible varieties (Lal and Pant, 1980). In resistant genotypes, early panicle exsertion and rapid internode development were related to lower larval establishment (Jotwani et al., 1971b, 1978; ICRISAT, 1986). Larval movement was also affected by a waxy bloom (Bernays et al., 1983).

Natural enemies are also known to suppress population buildup. Various numbers of parasites and predators attacking *C. partellus* have been reported (FAO, 1979). A braconid parasite, *Apanteles flavipes*, drastically reduces larval population (Pradhan, 1971). A case of introduction and establishment of *Trichogramma exiguum*, a parasitoid on *C. partellus* eggs, represents a notable success in India (Jotwani, 1982).

Cultural practices are highly relevant against this borer. Plowing and destroying crop residue are strongly recommended after harvest to reduce the diapausing larval population. Early planting also helps to reduce the severity of infestation, as mature plants are more resistant to initial larval attack. Granular formulation of carbofuran should be directly applied into the whorl, although this procedure is labor-intensive and is recommended only as a last resort (Taneja and Leuschner, 1985b). Sharma (1985) also listed nine insecticides that are effective against *C. partellus* in India.

Busseola fusca (Lepidoptera: Noctuidae)

Busseola fusca is a key pest of sorghum in Africa. It is distributed throughout the continent and attacks not only sorghum but also maize and millet. Newly hatched larvae of the species congregate and feed on young leaves in the plant funnel, destroying the growing point and resulting in deadheart symptom. More mature larvae bore into the stem and make extensive tunneling that may lead to lodging, although some studies showed that sorghum is considerably tolerant to infestation by this borer (Harris, 1962). Extensive surveys on sorghum stem borers in West Africa (Nwanze, 1985) showed that *B. fusca* is the dominant species in Nigeria, while its relative abundance decreased in relation to the other stem borer species (*Sesamia calamistis, Eldana saccharina*, and *Acigona ignefusalis*) along the drier northern areas.

In Nigeria (Harris, 1962) and Uganda (Ingram, 1958), a high *B. fusca* infestation rate was a sign of a well-grown crop, as the borer tended to attack more healthy, high-yielding stems than poor stands. Harris (1962) found that the diapausing pupae in stalks had the best chance of survival when the stalks were kept in stacks around villages in Nigeria. Dried sorghum stalks are used for fence and housing material and provide an active infestation source in the subsequent growing season. Adesiyun and Ajayi (1980) reported different practices of keeping sorghum stalks after harvest in rural Nigeria. When stacked vertically under the shade of trees, the stalks harbored the highest number of diapausing *B. fusca* larvae. Partial burning of stalks shortly after grain harvest slightly hardened the talks and killed 95 percent of the larvae. Cured stalks could then be used as housing and fence material. Spreading the partially burnt stalks horizontally in an open field further decreased larval survival. Farm hygiene and the removal of residual stalks and stubble also help reduce subsequent reinfestation. Early planting is recommended to reduce the severity of first generation infestation. With appropriate timing, chemical control by carbofuran and carbaryl is effective (Teetes et al., 1983).

Sesamia spp. (Lepidoptera:Noctuidae)

Sesamia spp. stem borers are distributed in Asia and throughout the African continent (Seshu Reddy and Omolo, 1985; Nwanze, 1985; Srivastava, 1985). They cause serious damages not only to sorghum but also to maize, sugarcane and millet. The larvae, which are nocturnal, migrate among plants, bore into the stem and consume the central shoot, thus causing deadheart (Srivastava, 1985). *Sesamia inferens* occurs in India, Southeast Asia and Japan. The species attacks sorghum and finger millet (*Eleusine coracana*) in southern states of India. Severe grain yield loss in sorghum ranged from 55 to 83 percent from multiple species of *Sesamia* in India (Jotwani et al., 1971b). Several *Sesamia* spp. in sorghum also occur in Africa. Among them, *S. calamistis* and *S. cretica* are considered to be more serious than the others. *Sesamia calamistis* is common throughout the continent, while *S. cretica* is distributed in eastern Africa and in the Middle East. In the forest zone of western Africa, *S. botanephaga* is predominant (Seshu Reddy and Omolo, 1985; Nwanze, 1985).

Control of *Sesamia* spp. are mainly by cultural practices (Teetes et al., 1983). Plowing, destroying and cleaning up the crop residues are strongly recommended. Early planting, careful weeding and removing alternate host plants also help reduce pest population buildup. Chemicals such as endosulfan and carbaryl are effective; although in subsistence level farming, especially in Africa, such commodities are either unavailable or practically too expensive (Seshu Reddy and Omolo, 1985).

Elasmopalpus lignosellus (Lepidoptera: Pyralidae)

The economic significance of the lesser corn borer *E. lignosellus* in the USA is limited to the southeastern region (Pitre, 1985). In Brazil, the species damages sorghum, maize, wheat, groundnut, soybean, beans, sugarcane and cotton (Viana, 1985). Stalk tunneling causes stunting; and weakened plants may easily lodge especially on sandy soil. Seedling and young plants when infested result in deadheart formation (Teetes et al., 1983). Effective control measures and determination of economic threshold levels are not yet well established. Currently recommended cultural practices in the USA involve reducing crop residue before planting, advancing the sowing schedule and crop rotation using nonhost plants. Granule and spray formulations of insecticides such as carbofuran are applied to the soil surface at planting, or to seedlings to protect the early stages of the plant from larval feeding (Pitre, 1985).

Panicle feeders

Contarinia sorghicola (Diptera: Cecidomyiidae)

The sorghum midge is cosmopolitan, directly affecting grain yield wherever sorghum is grown (Teetes et al., 1983). During their ephemeral life span (male fly, a few hours; female fly, about 24 hours), adult females oviposit within the florets. Upon hatching, the larvae feed on the developing ovaries, thereby hindering normal grain development. Severe infestation results in 'chaffy' or 'blasted' panicles with no grain formation.

The extent of damage by the species in Africa varies depending on the region. Across West Africa, midge incidence is usually low; while in Ghana where alternate wild host plants are available, infestation levels are often high (Bowden, 1965). As early as 1947, in the Indian subcontinent, Puttarudriah (1947) reported a compounded yield loss of 75 percent by midge and earhead bug. The severity of damage in the country became evident in 1965, when flowering panicles were continuously available due to staggered planting and use of late-maturing, local varieties (Srivastava, 1985).

Although the species is only an occasional pest in Southeast Asia, *C. sorghicola* is the most troublesome pest in Australia (Passlow et al., 1985). The diapausing larvae are capable of surviving in a wide range of environmental conditions (Passlow, 1965). Larval diapause coupled with the continuous availability of lowering host plants makes the midge proliferate in the contingent where sorghum production is rapidly expanding. Yield loss and associated cost of control are estimated to be large (4-8 million US dollars annually) (Passlow et al., 1985). In southern USA, the species ranks first in pest status (Pitre, 1988). In Mexico, yield losses of up to 75 percent were reported in northern states of Tamaulipas and Sinaloa (Diaz, 1985). Major infestation in Central America (Guatemala and El Salvador) has occurred in the Pacific coast (Salguero et al., 1979; Reyes and Andrews, 1981a). Sorghum midge is also a key pest in Brazil in areas with a humid climate (Viana, 1985).

Considerable studies have been made on the sorghum midge control and several practices can now be combined into IPM programs. In many countries, cultural control is widely practiced in early and uniform planting to escape midge damage. This practice controls the provision of flowering panicles for ovipositing females (Teetes et al., 1983). In Maharashtra State of India, the use of uniformly planted hybrids has virtually eliminated midge damage. When planting or flowering is staggered, insecticide treatment becomes necessary to control midge infestations. Insecticide application is based on the panicle flowering stage and the number of midge per panicle. In Australia, pyrethroid insecticide application has given good results (Passlow et al., 1985). A similar approach was undertaken in the USA (Teetes, 1976; Wiseman and Morrison, 1981), where the economic threshold for midge is 1-2 flies/panicle, depending on yield potential and cost of control (Young and Teetes, 1977). Similar studies are yet to be conducted in India and Africa where midge is also a serious pest.

Sorghum midge-resistant germplasm and breeding lines AF 28, SGIRL-MR 1, DJ 6514 and TAM 2566 are now available (Wiseman et al., 1973; Johnson et al., 1973; Johnson, 1975; ICRISAT, 1986) and hybrids are now widely used in the USA, India and Australia. Although screening for resistance is underway, the situation is much less advanced in Africa. Midge-resistant hybrids can save two insecticide applications at moderate midge densities (Teetes, 1985). Several studies have been reported on methods for screening sorghum entries for resistance and identification of resistance mechanisms (Rosetto, 1977; Wuensche, 1980; Bowden, 1965; Harris, 1962; Bergquist et al., 1974; Rosetto et al., 1975; Sharma, 1985). Among the characters identified are: nonpreference for oviposition, higher tannin content, short glume and high rate of ovary development.

Several species of natural enemies have also been reported from the USA (Harding, 1965; Lippincott and Teetes, 1983), Australia (Passlow, 1958), India (Seshu Reddy and Davies, 1979; Sharma, 1985) and Africa (Harris, 1962). These include general predators, hemipterans, chrysopid and coccinellid larvae, several parasitoids and several species of ants.

Calocoris angustatus (Hemiptera: Miridae)

The sorghum headbug *C. angustatus* is a serious pest in the southern part of India. Both nymphs and adults attack the grain by sucking it from milk to dough stage (Cherian et al., 1941). Feeding punctures are evident in heavily infested panicles. Hundreds of bugs can be found in a single panicle. Grain affected in the early development stages becomes shrivelled and results in yield loss. Compact-type heads are more severely damaged than open ones (Teetes et al., 1983).

Other related species of Hemiptera that attack sorghum panicles are: *Nezara viridula* and *Dysdercus koneigii* in India; *Eurystylus rufocunealis, Campylomma angustior* and *Campylomma subflava* in West Africa (Nwanze, 1985). *Eurystylus bellevoyei* was the most predominant mirid bug in Burkina Faso, while *E. rufocunealis* was more abundant in Nigeria (Nwanze, 1985). In Mali, *E. marginatus* was the predominant species of headbug (Sharma, 1985). *Nezara viridula* and other *Dysdercus* species are also present in East Africa.

Current control measures against headbugs, especially to *C. angustatus*, depend solely on chemical control. Liquid and dust formulations of carbaryl are applied to the head as contact insecticides (Subba Rao et al., 1980). Headbug-resistant varieties are yet to be identified although cultivars less susceptible to headbugs have been observed in Mali (Sharma, 1985).

Oebalus mexicana (Hemiptera: Pentatomidae)

Brown bug (*O. mexicana*) damage to sorghum head has been steadily increasing in Mexico since 1980. Up to 100 percent yield loss was reported in certain sorghum-growing areas (Diaz, 1985). The insect attacks young panicles by feeding on the grain. Repeated insecticidal treatments temporarily controlled the pest, but phytotoxicity was a problem. Control measures are progressively improved as the severity of damage caused by *O. mexicana* increases annually (Diaz, 1985).

Heliothis armigera (Lepidoptera: Noctuidae)

Heliothis armigera is widely distributed throughout Asia, Australia, Europe and Africa, but is not found in the Americas (Teetes et al., 1983). Its polyphagous nature is evident in the larval ability to proliferate in cotton, maize, tomato, tobacco and sorghum. Serious yield losses have been recorded in several states in India (Kulkarni et al., 1980). Estimated grain losses due to earhead caterpillars, including *H. armigera*, were 18.3 percent or 717 kg/ha (Rawat et al., 1970). Newly introduced high-yielding cultivars with large and compact earheads provide favorable microclimatic conditions and protection against predators and parasites, resulting in higher larval survival and crop damage (Srivastava, 1985).

Until recently, *H. armigera* was not regarded as a serious sorghum pest in Australia. But due to a prolonged growing season; sunflower, soybean and cotton plantings in the same area; and increased area planted to sorghum, this noctuid is now receiving considerable attention (Passlow et al., 1985). Heavy use of chemicals (pyrethroids) resulted in insecticidal resistance. In the summer of 1982-83, up to 80 percent larval survival was observed after applying insecticides. Coordination between research and grower in subsequent years appears to have improved the situation; the use of a nuclear polyhedrosis virus at commercial level is a promising control method (Passlow et al., 1985).

Another related species, *H. zea* (corn earworm), is a New World species and considered an occasional pest on sorghum grain (Wiseman, 1985). Cannibalism among larvae, parasites, predators and fungal and viral diseases take a heavy toll on various stages of *H. zea* (King et al., 1982; McKinley, 1982). Limited data are available on host plant resistance studies on *H. zea* and *H. armigera* (Oliver and Tipton, 1972).

Celama sorghiella (Lepidoptera: Arctiidae)

Celama sorghiella webworm is distributed in the more humid areas of the southern USA and in northeastern Mexico (Young, 1970; Diaz, 1985). It attacks panicles at flowering stage and can cause direct yield loss. Late flowering cultivars are more susceptible to infestation.

In the USA, cultural practices to control webworm involve early planting and destruction of crop residues. Sorghum varieties of open panicle type can help reduce infestation by providing easier access to natural enemies of webworm (Hobbs et al., 1979). Insecticide treatment with endosulfan is effective when sprayed under high pressure and directly over the sorghum head (Pitre, 1985).

DISCUSSION

This paper discussed the major pest species in sorghum. Over half of these belong to Lepidoptera, the larvae of which consume several parts of a growing sorghum plant. Among the Lepidoptera, stem borers constitute a major group, and together with the more cosmopolitan sorghum midge, inflict severe losses to the crop.

Although sorghum is the major staple cereal crop in Africa and Asia, the concept of sorghum pest control did not receive much attention until in the late 1960s and early 1970s when sorghum acreage rapidly expanded in the USA. This was further boosted by the development of high-yielding hybrids with moderately high fertilizer input and mechanical plowing. Then, sorghum insect pest control was solely based on insecticide use. Similarly, in Australia, where sorghum was introduced in the early 1930s, hybrids are generally grown and acreage is expanding (Passlow et al., 1985). Farmers of the semi-arid tropics of Africa grow sorghum as a subsistence crop with little or no inputs. In India, the situation has improved. Several hybrids are now grown by the farmers. The presence of reasonable infrastructure, increased land use and high human population have strikingly transformed India's agricultural sector (Davies and Seshu Reddy, 1980). Unfortunately, Africa is still lagging behind. Forecasts for its future are becoming gloomier as shortfalls in food production lead to food imports.

Currently available yield loss data have been obtained mainly from developed countries. While in Asia and Africa, where sorghum pests are considered as a problem, available data are only on infestation levels not on estimates of yield losses (Davies, 1982). Unfortunately, yield loss data are the basis for determining research priorities and resource allocation in Asia and Africa. Similarly, while economic thresholds have been determined for several species in the USA and Australia, such data do not exist for any particular species in Asia and Africa; yet this is vital in determining when and where control operations should be initiated. Consequently, the favorable results obtained in chemical control using insecticides in the sorghum areas of developed countries have been directly tested at research stations in the developing countries. But many insects in the development world, particularly midge and stem borers, cannot be easily controlled by existing techniques. Furthermore, subsistence agriculture in the semi-arid tropics would not allow the investment, nor does an incentive for such inputs exists. As with insecticides, while the use of host plant resistance appeals to developing countries, resistant genotypes developed in the advanced nations cannot simply be transferred to Africa, for instance. In many cases, the breeder has a wide range of crops to deal with and there may not be an entomologist on the staff to incorporate pest-resistant characters into the hybrids.

The wealth of information on sorghum pest control from developed countries should then be carefully integrated to fit into the farming systems of developing countries. This implies that current cultural practices prevalent in subsistence agriculture should form the basis upon which other methods – chemical, biological and host plant resistance – should be incorporated. There is clearly a need to evaluate various approaches under particular local conditions.

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Table 1
World occurrence of major sorghum pests

Scientific name	Order: Family	Common name	Distribution
Soil insect pests			
Holotrichia serrata	Coleoptera: Scarabaeidae	May or June Beetle	India
Lachnosterna consanguinea	Coleoptera: Scarabaeidae		
Seedling pests			
Atherigona soccata	Diptera: Muscidae	Shoot fly	Eurasia, Africa
Foliage feeders			
Patanga succincta	Orthoptera: Acrididae	Grasshopper	Thailand
Spodoptera frugiperda	Lepidoptera: Noctuidae	Fall armyworm	Americas
Mythimna unipuncta	Lepidoptera: Noctuidae	Armyworm	Mexico
Mythimna separata	Lepidoptera: Noctuidae	Oriental armyworm	Asia, Australia
Schizaphis graminum	Homoptera: Aphididae	Greenbug	cosmopolitan
Rhopalosiphum maidis	Homoptera: Aphididae	Corn leaf aphid	cosmopolitan
Oligonychus pratensis	Acarina: Tetranychidae	Banks' grass mite	USA
Stem borers			
Chilo partellus	Lepidoptera: Pyralidae	Spotted stem borer	India, Asia, E. Africa
Busseola fusca	Lepidoptera: Noctuidae	Maize stalk borer	Africa
Sesamia spp.	Lepidoptera: Noctuidae	Pink borers	Asia, Africa
Elasmopalpus lignosellus	Lepidoptera: Pyralidae	Lesser cornstalk borer	Americas
Panicle feeders			
Contarinia sorghicola	Diptera: Cecidomyiidae	Sorghum midge	cosmopolitan
Calocoris angustatus	Hemiptera: Miridae	Earhead bug	India, Africa
Oebalus mexicana	Hemiptera: Pentatomidae	Brown bug	Mexico
Heliothis armigera	Lepidoptera: Noctuidae	Bollworm	Eurasia, Africa, Australia
Celama sorghiella	Lepidoptera: Arctiidae	Sorghum webworm	Americas

Table 2
Crop damage associated with major sorghum pest and current control measures in respective region

Species	Plant part attacked/ damage symptom	Control measure	Remarks
Soil insect pests			
Holotrichia serrata	Root system/poor stand,	Capturing adults	May or June Beetle
Lachnosterna consanguinea	stunted plants, lodging	manually	
Seedling pests			
Atherigona soccata	Central shoot, growing point/deadheart	Early, uniform planting, systemic insecticides host plant resistance (glossy leaves, antibiosis)	Not found in Americas, Australia
Foliage feeders			
Patanga succincta	All leaf stage/defoliation	Cultural control	General feeder in Asia
Spodoptera frugiperda	All parts except root/ shot-holed leaves, stem tunneling	Natural enemies, cultural control	New World species
Mythimna unipuncta	Young leaves/defoliation	Chemical control	
Mythimna separata	Leaves/only midribs left uneaten	Natural enemy, host plant resistance	Nocturnal feeder

Table 2 (Cont.)

Species	Plant part attacked/ damage symptom	Control measure	Remarks
Schizaphis graminum	Mainly leaves, seedling, panicle also/leaf reddening, sticky honeydew	Natural enemies, organophosphorous insecticides, resistant varieties	Transmit maize mosaic virus
Rhopalosiphum maidis	Leaf whorl, stem, panicle/ similar to the above	Systemic insecticides, natural enemies	Transmit maize mosaic virus
Oligonychus pratensis	Underside of leaves, fine webbing/yellowing leaves	Natural enemies. acaricides	Phytophagous mite
Stem borers			
Chilo partellus	All parts except root/ deadheart, shot-holed leaves, stem tunneling	Host plant resistance (ovipositional non-preference, antibiosis) natural enemies, cleaning crop residue, early, uniform planting	Serious in India, E. Africa
Busseola fusca	Tender leaves, stem/ deadheart, stem tunneling	Cleaning crop residue, early planting, lightly burning stalks	Also infest maize, millet
Sesamia spp.	Shoot, whorl leaves/ deadheart, stem tunneling, lodging	Cleaning crop residue, early, uniform planting	Also attack maize, millet, nocturnal larvae
Elasmopalpus lignosellas	Stem tunneling, stunted plants, lodging, deadheart	Cleaning crop residue, early planting, soil surface spraying	
Panicle feeders			
Contarinia sorghicola	Flowering panicle/ no grain formation	Early, uniform planting, host plant resistance (resistant germplasm and breeding lines available)	Sorghum midge IPM
Calocoris angustatus	Developing grain/ shrivelled grain	Chemical control	Serious in southern India
Oebalus mexicana	Developing grain/ no grain formation	Chemical control	Recent outbreaks in central Mexico
Heliothis armigera	Developing grain, young whorl leaves/yield loss	Natural enemies, larval diseases, cultural control	Polyphagous larvae
Celama sorghiella	Flowering panicle, tender grain/yield loss	Early planting, cleaning crop residues, open-panicle varieties	Prevalent in humid USA