INSECT PESTS OF SORGHUM

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This chapter presents a practical approach involving the use of multiple methods to manage insect pests of sorghum, *Sorghum bicolor* (L.) Moench. The approach emphasizes ways to avoid and prevent damaging insect pest infestations, and estimate insect abundance and evaluate severity of damage to determine when remedial action with insecticide is justified. Insect pests (including color plates), their biologies, and natures and symptoms of damage are described. This information assists in the proper identification of the insect, explains how the insect lives and causes damage, and describes symptoms of damage. In other words, information in this chapter provides the "tools for decision making" regarding insects that infest sorghum. Information on insect pests of stored sorghum or natural enemies attacking sorghum insect pests is not necessarily specific to sorghum.

Insect pests in the United States are more thoroughly covered than are those from other areas of the world.

Modern sorghum is a product of human ingenuity. It has been domesticated and changed to meet human needs. The crop grows well as landrace varieties by using primitive cultivation in small, subsistence plots or as hybrids by using the most modern production practices and equipment in vast monocultures. Commonly, sorghum is grown in areas too hot and too dry to produce other crops such as maize, *Zea mays* L. Sorghum is known for its production reliability. But, this crop may be infested by an array of insect species and a few species of spider mites, several of which frequently threaten yield.

Some insect pests infest and damage sorghum at about any plant growth stage while others cause economic damage only at specific plant growth stages (Figure 1).

Most insect species infesting sorghum are distributed widely, are not host specific, and did not coevolve with sorghum. In sorghum agroecosystems, one or two key insect pests such as greenbug, *Schizaphis graminum* (Rondani), sorghum midge, *Stenodiplosis sorghicola* (Coquillett), shoot fly, *Atherigona soccata* (Rondani), or several stalk-boring species occur perennially and dominate control practices. Several species such as Banks grass mite, *Oligonychus pratensis* (Banks), or corn earworm, *Helicoverpa zea* (Boddie), are secondary or induced pests that become injurious as a result of insecticides applied for a key pest. Most other insects that infest sorghum are occasional pests that cause economic damage only in localized areas or only during some years. Occasional insect pests include wireworms, families Elateridae and Tenebrionidae; white grubs, *Phyllophaga* spp.; cutworms, family Noctuidae; aphids, family Aphididae; leaf- and panicle-feeding caterpillars, family Noctuidae; stalk-borers, family Pyralidae; and leaf- and panicle-feeding bugs, order Hemiptera.

Insect pests of sorghum should be managed by actions taken that prevent insects from becoming abundant enough to cause economic damage. Management actions include using nonchemical and chemical methods. Cultural and biological management methods are nonchemical methods imposed to avoid insect pests, suppress insect pest abundance or rate of increase, delay the time when insect pests reach damaging abundance levels, or increase plant tolerance to insect pests. Because nonchemical management methods are imposed to avoid or prevent insect pest damage, the decision to use these methods must be made before an insect pest problem occurs, and often even before the crop is planted. Chemical management methods involve use of insecticides to

kill insect pests. Insecticides have rapid, curative action but are costly and may cause negative ecological and environmental consequences. Therefore, their use must be justified based on actual measurement of insect abundance and damage. Integrated pest management (IPM) involves the use of a combination of management methods in a strategy to maintain insect pest abundance or damage below levels that cause economic loss. IPM is a practical approach to dealing with insect pests of sorghum.

Cultural, Biological, and Chemical Management Methods

Cultural Management Methods

Crop production practices may enhance or suppress survival, abundance, and severity of damage of sorghum insect pests. These practices can be used to avoid conditions that favor insect pests or activate conditions detrimental to an increase in insect pest abundance or damage.

Crop termination and alternate host elimination are cultural management methods that increase mortality of insect pests and decrease subsequent damage through destruction of food sources and overwintering habitats. Destroying the crop soon after harvest and eliminating volunteer sorghum plants suppresses insect pest abundance the following year. Destroying alternate host plants eliminates sources of insect pests that infest sorghum. Tillage methods for sorghum vary regionally and have evolved from plowing with a moldboard plow, followed by several secondary tillage operations, to much reduced tillage. The trend is toward combining secondary tillage and planting into one trip over the field. Whatever tillage is used, sorghum stalks should be destroyed soon after harvest to expose and kill insect pests and eliminate their food supply. It is equally important to destroy volunteer sorghum and alternate host plants that harbor insect pests. Herbicides can be used to kill sorghum and alternate host

plants where reduced tillage is used. However, failure to destroy overwintering sites mechanically may contribute to an increase in the survival of certain insect pests.

Destroying food sources and overwintering habitats reduce abundance of cutworms; sorghum midge; sorghum webworm, *Nola sorghiella* Riley; sugarcane borer, *Diatraea saccharalis* (Fabricius); and sugarcane rootstock weevil, *Anacentrinus deplanatus* (Casey). Johnsongrass, *S. halepense* (L.) Pers., is a noncultivated host of many sorghum insect pests, including yellow sugarcane aphid, *Sipha flava* (Forbes); greenbug; and sorghum midge. Destroying this weed is difficult but highly beneficial to efficient sorghum insect pest management and crop production.

Crop rotation is a cultural management method that involves alternate use of host and nonhost crops in a field to reduce insect pest abundance and damage. Sorghum benefits most when rotated with a broadleaf or taprooted crop such as cotton, *Gossypium hirsutum* L., or soybean, *Glycine max* (L.) Merr. Growing sorghum in a field planted to a different, nonhost crop the previous year significantly reduces the abundance of some insect pests, as well as some diseases and weeds.

Crop rotation is most effective against insect pests with a limited host range, long life cycle (one or fewer generations a year), and limited ability to move from one field to another. For example, several species of wireworms, white grubs, and some cutworms have only one generation a year, must have a grass-type crop on which to develop and reproduce, and because they live underground cannot during the damaging larval stage move from one field to another. Thus, growing a nongrass crop such as cotton or soybean the year before growing sorghum reduces abundance of soil-inhabiting insect pests in sorghum fields. Sorghum should be rotated annually with other crops.

Variety selection, seedbed preparation, and seed treatment are important for managing sorghum insect pests. Only sorghum varieties with seed germination of eighty percent or greater should be used. Poor seed germination results in reduced stands and less competitive plants more susceptible to damage by insects. A sorghum variety adapted to the locale, and preferably one least vulnerable to insect pests and diseases, should be used. Sorghum hybrids selected should be resistant to greenbug. Sorghum midge-resistant hybrids, if available, are useful in more southern regions of the United States. Larvae of corn earworm; fall armyworm, *Spodoptera frugiperda* (J. E. Smith); and sorghum webworm that consume developing kernels infest sorghum hybrids with open panicles less than those with compact panicles. Also, kernels of open-panicle sorghum varieties are less likely to deteriorate from the combined effects of weather and damage by panicle-infesting bugs and pathogens. Sorghum varieties should be selected that mature as early and uniformly as practical in a locale. These varieties escape infestation by sorghum midge, corn earworm, fall armyworm, sorghum webworm, and sugarcane borer.

Sorghum varieties resistant to pathogens and lodging also lessen detrimental effects from insect pests. Insect pests stress sorghum plants, and this stress combined with pathogen infection increases the chance of plant lodging. Greenbug and corn leaf aphid, *Rhopalosiphum maidis* (Fitch), transmit maize dwarf mosaic virus to sorghum. This problem is best dealt with by using virus-resistant varieties. Iron-tolerant sorghum varieties should be used in areas where iron deficiency is a problem.

Well-prepared seedbeds speed seed germination and seedling growth. The trend in planting sorghum is less tillage and fewer trips over the field using appropriate planting equipment. Tillage for seedbed preparation should modify the soil to allow desired control of seed placement, weeds, water infiltration, water evaporation, and erosion.

Rapid seed germination is essential to avoiding damage by seed-feeding insects such as wireworms and red imported fire ant, *Solenopsis invicta* Buren. Rapidly growing and larger plants better tolerate damage by yellow sugarcane aphid, greenbug, and chinch bug, *Blissus leucopterus leucopterus* (Say).

Insecticide can be used to protect planted seed from insect pests. Recently, sorghum seed treated commercially with a systemic insecticide is available to protect against seed-feeding insects and some seedling insect pests. Also, insecticides can be applied to seed in the planter box or in-furrow at planting. Systemic in-furrow insecticide protects seedling sorghum against some insect pests. Insects controlled by systemic seed or in-furrow treatment include wireworms, red imported fire ant, cutworms, southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber, aphids, and chinch bug.

Planting time of sorghum in most locales should be as early as practical but not when soil is too cool for rapid seed germination and seedling growth. In many areas, early planting takes advantage of seasonal rainfall. Planting early avoids infestation and damage because the sorghum plant is beyond the vulnerable stage when some insect pests are abundant enough to cause damage, or at the very least, the crop is susceptible for a shorter period of time.

Early and uniform planting of sorghum to avoid a damaging sorghum midge infestation is an excellent example of the benefit of planting early. Planting sorghum early avoids high numbers of corn earworm, fall armyworm, sorghum webworm, stalk borers, and panicle-feeding bugs.

Fertilizer and water applied to sorghum either can be beneficial or detrimental to insect pests. Using too much fertilizer and irrigation can cause sorghum plants to be especially succulent and attractive to insect pests, and may extend the time to maturity,

increasing the duration of vulnerability. On the other hand, healthy, vigorously growing sorghum plants better tolerate insect pest infestation and other stresses. Chinch bug and Banks grass mite are favored by hot, dry conditions and moisture-stressed plants. Yield of healthy plants is less reduced by most leaf-feeding insect pests. In some areas, application of iron is important for production of healthy sorghum plants.

Biological Management Methods

Biological management methods reduce insect pest abundance and damage by use of natural enemies. Natural enemies include predators, parasites, and pathogens that kill insect pests. Natural enemies can be used in three ways: classical or importation is control of insect pests using introduced natural enemies, augmentation is mass culturing and periodic release of a natural enemy, and conservation or preservation is enhancement of numbers of already existing natural enemies. Conservation currently is the most applicable biological management method to suppress abundance of sorghum insect pests.

Conservation of natural enemies involves protecting existing natural enemies so they are abundant enough to suppress the insect pests they attack. Sorghum hosts an abundance of natural enemies, primarily because of aphids that infest the crop. The corn leaf aphid, usually noninjurious to sorghum, often becomes very abundant. Corn leaf aphids attract many natural enemies that attack and reduce the abundance of aphid and caterpillar pests. However, most insecticides used in sorghum are broad spectrum and kill natural enemies as well as pest insects. The negative effect of insecticides on natural enemies is a primary reason for making certain insecticides are needed before they are applied. When natural enemies are destroyed, there is no natural protection against insect

pests. This results in resurgence of the treated pest or allows a secondary pest such as corn earworm or Banks grass mite to increase in abundance.

Sorghum insect pests most affected by natural enemies are greenbug, yellow sugarcane aphid, corn earworm, fall armyworm, sorghum webworm, and Banks grass mite. Predators affect the abundance and rate of increase of greenbug, especially during early season, and often prevent economic damage. This is true particularly when greenbug-resistant hybrids are used. Parasites often terminate greenbug infestations late in the season. Predators suppress the abundance of corn earworm and fall armyworm that infest sorghum panicles. The sorghum midge is attacked by several parasites, but their effect is minimal. Several pathogens, mostly fungi, infect insect pests. Chinch bug, corn earworm, and fall armyworm are insect pests most affected by naturally occurring pathogens.

Chemical Management Methods

Insecticides are chemicals that kill insects. They are powerful tools for controlling insect pests of sorghum. Their major advantage is that they are the only practical control for insect pests at or approaching economically damaging abundance levels. Insecticides kill rapidly and are easy to apply. Key disadvantages of insecticides are cost and broad toxicity. They adversely affect nontarget organisms in the crop and nearby areas. From a sorghum insect pest management standpoint, cost and killing natural enemies are of most concern. Human health and environmental problems associated with using insecticides increase the importance of preventive management methods and justified need for insecticide application.

Insecticides should be used in the proper amounts and only when necessary to prevent economic loss. Cost of totally eliminating insect pests with insecticides can

exceed benefits. Insecticides should be applied only when insect pest abundance is increasing and expected to exceed the economic injury level if not suppressed. The economic injury level is the insect pest abundance or amount of damage that causes economic crop loss greater than the cost of controlling the pest. An economic threshold level is an insect pest abundance or damage level before the economic injury level is reached, and is when control measures should be applied. Costs for insecticide and application, prevailing crop market price, and expected yield all must be considered when deciding to use an insecticide. Insect pest abundance, age, and duration of attack, as well as stage and condition of the plants attacked, also must be considered.

Insecticides can be timed or used in ways to preserve naturally occurring predators and parasites of sorghum insect pests. For example, many predators and parasites will be spared if extremely low rates of insecticide are used when greenbug abundance reaches the economic threshold. This technique can be used, however, only where greenbugs are highly susceptible to insecticides. Spider mites are resistant to insecticides, and insecticide applications can destroy natural enemies and disperse spider mites on infested plants, releasing the reproductive inhibitory effect of crowded colonies that enable spider mites to rapidly increase in abundance.

Insect Pests in the United States

Numerous insects attack sorghum in the United States. Summarized in Table 1 and described in detail in the following pages, are the insect pests, their biologies, natures and symptoms of damage, and management actions. The insect pests of sorghum are grouped according to the plant parts they attack.

Insect Pests of Seed and Roots

Wireworms, false wireworms, red imported fire ant, white grubs, cutworms, and corn rootworms can damage planted seed and underground parts of sorghum plants and cause plant stand loss or stunting.

Wireworms: *Aeolus* spp.; *Eleodes* spp.; *Conoderus* spp.

Description and Biology: Several species of wireworms attack planted sorghum seed. True wireworms are immature stages of click beetles, family Elateridae. False wireworms are immature darkling beetles, family Tenebrionidae. Wireworms are shiny, slender, cylindrical, smooth, and hard-bodied larvae ranging in color from white to yellow or brown, and are about 25 mm long when grown (Color Plate 1). The last segment of the larva usually is ornamented.

All life stages of wireworms except the adult develop in the soil. Depending on the species, a generation is completed in one, two, or more years. Wireworms usually overwinter in the damaging larval stage and are present in the soil at the time sorghum seed are planted in the spring.

Damage and Symptoms: Wireworms feed on and damage planted sorghum seed. Wireworms feed less on seedling roots. Seeds hollowed out by larvae do not germinate, thus reducing plant stand. Evidence of wireworm damage to sorghum is a nonuniform plant stand with stunted, weak seedlings.

Monitoring: Soil in fields should be inspected for wireworms before sorghum is planted. However, visually locating wireworms in soil is difficult. Wireworm abundance can be assessed by placing about 300 g of nontreated sorghum seed in a 12-cm-wide hole at least 10 cm deep, deep enough to reach moist soil. After covering the hole with soil, the baited trap should be covered with a 1-m^2 sheet of black plastic that warms the

soil and attracts wireworms to the warmed soil and grain. The trap should be marked with a stake. One trap for each 2.5 to 5 ha of field should be installed at least two weeks before planting. Grain in the trap should be examined two weeks after placement and wireworms counted. Two or more wireworm larvae per trap are sufficient to cause stand loss and justify the use of insecticide, especially if conditions are not good for rapid seed germination.

Management: The amount of damage to sorghum depends on the number of wireworms in the field at the time of planting and the length of time seed are in the soil before they germinate. The seedbed should be prepared properly and seed planted at a time to ensure rapid seed germination. Sorghum should be planted in a field where a nongrass crop was grown the previous year. Also, tillage before planting reduces noncrop plants in the field. Insecticide applied to seed or in the planter-box usually is effective in controlling wireworms. Seed may be purchased already treated with a systemic insecticide that protects against wireworms. In-furrow insecticide applications also control wireworms. When wireworms are abundant, seed treatment should be supplemented with a granular or liquid insecticide applied to soil at planting.

Red Imported Fire Ant, *Solenopsis invicta* Buren

Description and Biology: The red imported fire ant, known for its painful sting and venom that produces a unique white pustule, has replaced many native ants in areas it infests. Red imported fire ant colonies consist of the brood (eggs, larvae, and pupae) and several castes of adults. Adults include winged males with smaller heads and darker bodies than females, red to brown winged females, one or more queens, and workers. Worker ants are wingless, sterile females, and vary in size (Color Plate 2). Older workers forage or defend the nest while younger workers care for the brood.

A newly mated queen lays a cluster of a dozen or more eggs. When the eggs hatch six to ten days later, the queen feeds the larvae infertile eggs, regurgitated oil from her crop, or protein secretions from her salivary glands. An older queen can lay 200 eggs each day. Older larvae receive food gathered by worker ants. Larvae develop in six to ten days, and pupate. Adults emerge nine to fifteen days later. The average colony contains 100 000 to 500 000 workers, several hundred winged forms, and one or more queens. Queen ants live for five or more years.

A new colony does not produce a conspicuous mound for several months. Mounds are built in almost any kind of soil, but open, sunny areas such as pastures, meadows, and cultivated fields are preferred. The size of a mound depends on soil characteristics and land disturbance, but mounds can be 25 to 30 cm tall. Mounds are smaller in sandy soil. Mounds often are located in rotting logs, around stumps and trees, and occasionally under buildings.

Symptoms and Damage: Although considered in some agricultural situations to be beneficial because they consume other insects, red imported fire ants feed on planted sorghum seed. They occasionally damage roots and leaflets of germinating seeds. Worker ants chew through the thin seed coat and remove the embryo (germ). Rarely is the endosperm (starch) of the seed consumed. Water-soaked or germinating seeds are preferred, but dry seeds also are damaged. The embryo and some of the surrounding endosperm are hollowed out, leaving a ragged and pitted hole. This damage results in loss of seed germination, causing reduced sorghum plant stands.

Management: Production practices helpful in reducing the effects of wireworms on planted sorghum seed also reduce damage by red imported fire ant. Rapid seed germination is very important. Amount of damage caused by red imported fire ant to

sorghum is influenced by the length of time the seed is vulnerable (dry and germinating) and by the abundance of the ants. In addition to using seed treated with insecticide, seed with good vigor should be planted into a well-prepared seedbed. Soil should be packed firmly, particularly during dry conditions, to cover seeds and make them less accessible. Red imported fire ant is more abundant in fields that receive reduced-tillage compared to those that receive extensive tillage.

White Grub, *Phyllophaga crinita* (Burmeister)

Description and Biology: The adult white grub is a May or June beetle, but only the larva, "C"-shaped with a white body and tan or brown head, damages sorghum (Color Plate 3). The larvae feed on sorghum roots. A fully-grown larva is 20 to 25 mm long. Dark-colored, nondigested food can be seen through the smooth, shiny, transparent, last abdominal segment of the larva. Two rows of minute hairs on the underside of the last segment distinguish white grubs from similar-looking larvae. White grubs overwinter as larvae so are present in the damaging stage when sorghum is planted in the spring. Depending on the species, a life cycle may require one, two, or more years.

Symptoms and Damage: Damage results from larvae feeding on roots. The most obvious and significant damage occurs during the spring soon after sorghum plants emerge from the soil. Seed germination occurs and a satisfactory stand is established, but damage to roots causes seedlings less than 15 cm tall to die. Stand loss can occur within seven to ten days after plants emerge in severely infested fields. One white grub can destroy plants along 0.3 to 0.5 m of a row. Infested plants not killed as seedlings are severely stunted and may never produce grain. A third kind of damage is root pruning by overwintered as well as current-season larvae. Injured plants may produce panicles after such damage but frequently do not have sufficient roots to prevent lodging. Occasionally,

lodging is increased by secondary stalk rot organisms. Figure 2 illustrates the economic effect to sorghum of white grubs at different abundance levels.

Monitoring: Three important considerations when sampling for white grubs are: 1. the insect overwinters in the last larval instar and is present in the soil when sorghum is planted, 2. the presence of larvae must be determined before sorghum is planted, and 3. effective control measures cannot be applied after the crop is planted. To determine the presence and abundance of white grubs in a field before planting, soil in a 32-cm^2 area should be excavated with a shovel and examined for grubs. Temperature affects the depth white grubs are in the soil. During cool winter months, white grubs may be 32 cm or more deep in the soil. However, in spring grubs become active and may be only 7 to 12 cm deep. One half or more grub in each sample of soil can cause economic damage to sorghum. White grubs sometimes are seen during disking or other tillage activities. Sampling soil for white grubs is the only way to accurately assess abundance.

Management: Planting sorghum in a field where a nongrass crop was grown the previous year is the most important cultural management tactic against white grubs. Preplant application of registered insecticides is effective but expensive because the insecticide must be broadcast and then incorporated into the soil. Some suppression of white grub abundance can be achieved by using an in-furrow or band application of insecticide at planting.

Insect Pests of Seedlings

Cutworms: Numerous species, Family Noctuidae

Description and Biology: Cutworms are the larval stage of nocturnal moths, several species of which damage sorghum. The typical cutworm larva attacking sorghum has a plump, curled-up appearance (Color Plate 4). Larvae are smooth, but vary in color from

grayish-white to grayish-black or brown depending on species. Fully-grown larvae are 30 to 50 mm long. Most cutworms overwinter as partly- to fully-grown larvae. Some species, however, hibernate as adults, and others hibernate as pupae in the soil. Cutworms usually overwinter in cells in the soil, under trash, or in clumps of grass. They start feeding in the spring and grow until summer, then pupate in the soil. Depending on species, generations per year vary from one to five. Larvae of most species remain underground during the day and emerge to feed at night. Eggs are laid on stems or leaves of grasses, such as sorghum, or weeds, or on soil. Eggs hatch in two to fourteen days. Some species prefer to lay eggs in low areas of fields or those subject to flooding. Often weeds are abundant in these areas.

Symptoms and Damage: Cutworms of different species may damage sorghum plants in three ways: 1. some cut off sorghum plants at or slightly below the surface of the soil (surface-feeding cutworms), 2. some feed on above-ground plant parts (climbing or army cutworms), 3. others feed on underground plant parts including roots of seedlings (subterranean cutworms). Plants with severed stems die. Leaf feeding by cutworms causes ragged leaves, while root-feeding cutworms kill small plants or stunt larger plants.

Monitoring: Cutworms are detected by visible damage to sorghum plants. For surface-feeding cutworms, the number of severed plants per meter of row should be determined. A decision to apply insecticide should be based on the degree to which an adequate stand is threatened. Significant loss occurs when about thirty percent of leaf tissue has been eaten by cutworms that feed on above-ground plant parts. Cutworms that feed below ground should be sampled before planting sorghum, especially in areas with a history of subterranean species.

Management: Cultural management include tillage to destroy vegetation in late summer or early fall, thoroughly preparing the seedbed three to six weeks before planting, and controlling weeds. Cutworms are more abundant in weedy fields. Herbicides may be used to kill winter weeds, thus reducing the potential for damage by cutworms. Insecticide can be used against cutworms in sorghum, but effectiveness of control can vary greatly. Because cutworms hide in the soil during the day, late-afternoon applications sometimes are more effective. Poisoned baits are effective against some species, but are expensive. Subterranean cutworms can be suppressed with insecticide applied to soil at planting. Insecticide applied as a 15- to 18-cm band at planting should be incorporated into the top 2.5 to 5 cm of soil. Aerial or ground application of insecticide controls cutworms feeding above ground on sorghum plants. Such insecticide applications are more effective on surface and climbing than subterranean cutworms. Also, insecticide is more effective when the soil is moist.

Southern Corn Rootworm, *Diabrotica undecimpuncta howardi* Barber

Description and Biology: The larva of this pest is the southern corn rootworm; the adult is the spotted cucumber beetle. The larva, slender with a brown head and white or pale-yellow, wrinkled body, grows to about 15 mm long (Color Plate 5). The last segment of the abdomen has an almost circular margin and is brown. The 6-mm-long adult beetle is yellowish-green with eleven black spots on its forewings. It has a black head and antennae one-half to two-thirds the length of the body. The adult overwinters in shelters of trash, or is active during mild winters. In spring, females deposit eggs in the soil around the base of plants. There are two generations a year.

Symptoms and Damage: The southern corn rootworm feeds on and bores into roots of sorghum or enters the stalk just above the roots. It feeds in the crown area of

young plants, destroying the apical meristem and preventing growth of the main stem. Symptoms of damage are stunting and “deadhearts.” Young plants are most affected. Delayed and nonuniform maturity may result from production of tillers. Plant lodging may occur later in the season.

Monitoring: Southern corn rootworm cannot be controlled after the crop is planted, and abundance cannot be determined before planting. A history of southern corn rootworms in a field is the only way to assess the need to apply insecticide for control. This fact increases the importance of appropriate cultural practices.

Management: Cultural management practices include keeping fields free of grassy weeds, plowing and disking thirty days before planting, rotating with a nongrass crop, planting early, and planting at a slightly higher than normal seeding rate. In-furrow, at-planting application of granular or liquid insecticide also is effective.

Yellow Sugarcane Aphid, *Sipha flava* (Forbes)

Description and Biology: The yellow sugarcane aphid is usually lemon yellow but under some conditions is pale green, 2 mm long, covered with short, black spines, and has two double rows of dark spots on its back (Color Plate 6). Cornicles are very short. Winged and wingless forms live in the colony. The wide range of wild hosts includes johnsongrass and dallisgrass, *Paspalum dilatatum* Poir. Without mating, females give birth for twenty-eight days to living young. Each female produces an average of two nymphs per day. Nymphs mature in thirteen to nineteen days.

Symptoms and Damage: Yellow sugarcane aphids feed on the underside of lower sorghum leaves and inject toxin. Aphids cause purple-colored leaves on seedling sorghum and yellow leaves on more mature plants. Plants not killed are severely stunted, and maturity of even slightly damaged plants is delayed. By the time discoloration

symptoms are visible, plants have been injured significantly (Table 2). Very few aphids on a seedling plant can cause severe damage. Damage often causes plant lodging that may be enhanced by associated stalk rots.

Monitoring: The presence of yellow sugarcane aphids must be determined soon after sorghum plants emerge. Often the abundance of yellow sugarcane aphids can be determined at planting time by the abundance of these aphids on nearby johnsongrass or dallisgrass. The presence of purple-colored seedling plants is a possible indication of a yellow sugarcane aphid infestation; however, leaf purpling also can be caused by cold weather and other factors. Sorghum plants should be inspected beginning the first week of plant emergence and twice weekly until plants have at least five true leaves. Yellow sugarcane aphids most damage small sorghum plants. Very small sorghum seedlings (one to three true leaves) often are damaged significantly after being infested for a week or less. As plants grow larger, they better tolerate aphid feeding.

Figure 3 illustrates the economic impact of yellow sugarcane aphids at different infestation levels. An insecticide application would be justified when ten to forty percent of plants at the one- to three-leaf stages are infested. In Table 3 is detailed information on the relationship of yellow sugarcane aphid abundance to control cost and crop value.

Management: Many predators feed on the yellow sugarcane aphid, but the aphid rarely is parasitized. Planting when conditions are favorable for rapid seedling growth is important because larger plants are less damaged than smaller plants. Several foliar insecticides, if applied soon after infestation occurs, effectively control yellow sugarcane aphids in sorghum. Some systemic insecticides applied to seed or in-furrow at planting also control yellow sugarcane aphid.

Chinch Bug, *Blissus leucopterus leucopterus* (Say)

Description and Biology: Nymphs of chinch bug are pale yellow when hatched but soon become red except for the first two abdominal segments that remain pale (Color Plate 7). Subsequent instars become darker red but retain a pale-yellow band across the front part of the abdomen. The last nymphal instar is black and gray with a conspicuous white spot on the back between the wing pads. The 4.2-mm-long adult chinch bug is black, with reddish-yellow legs, and conspicuous white forewings, each of which has a black triangular spot at the middle of the outer margin. Chinch bugs overwinter as adults in bunch grass. In spring, they migrate from overwintering sites to small grains where they lay eggs. Chinch bug eggs are laid behind lower leaf sheaths of host plants, on roots, or in the soil near hosts. Nymphs of this first generation migrate to sorghum and other hosts such as corn. In southern regions, adults may move directly from overwintering sites to sorghum without first infesting small grains. The life cycle is completed in thirty to forty days. A second generation develops and disperses within the host crop field, and there may be an additional generation in southern regions.

Symptoms and Damage: Chinch bug adults and nymphs damage plants by withdrawing large amounts of juices from stems or underground plant parts. Young plants are highly susceptible to damage. Older plants withstand more chinch bugs than smaller plants, but they, too, become reddened, weakened, and stunted, and frequently lodge. Chinch bug outbreaks are favored by dry weather.

Monitoring: Careful examination of plants, especially behind leaf sheaths and soil around plants, is required to locate chinch bugs. Plants at no less than five random sites should be exmined in a field. Small plants and soil, especially loose, dry soil where chinch bugs often feed, should be carefully examined. On large plants, chinch bugs most commonly are found behind leaf sheaths. Insecticide should be applied when two or more

adult chinch bugs are found on twenty percent of seedlings less than 15 cm tall. On taller plants, control may be warranted when there are four or five nymph or adult bugs per plant (Figure 4). Generally, one chinch bug per sorghum seedling results in approximately two percent grain yield loss. Fifteen chinch bugs per plant can reduce crop value thirty-three percent.

Management: Cultural management practices that stimulate dense, vigorous sorghum stands are recommended to suppress chinch bugs and injury. Sorghum should be planted as early as possible. Chinch bugs sometimes are difficult to control with insecticide. Systemic insecticide applied for soil insect pests to seed or at planting for soil insect pests control chinch bugs. At-planting, soil-incorporated insecticide may be justified in fields with a history of economically damaging infestations of chinch bug. Granular products must receive after application about 13 mm of rain to be effective in suppressing early season chinch bug infestations. Insecticide application to plant foliage may be justified if infestations reach the economic threshold. When using ground application equipment, insecticide should be applied in at least 93.5 liters of water per hectare through nozzles directed at the base of plants. Satisfactory control seldom is obtained on plants in the boot stage or older. Insecticide applied by aircraft seldom is effective or recommended.

Insect Pests of Leaves and Leaf Whorls

Corn Leaf Aphid, *Rhopalosiphum maidis* (Fitch)

Description and Biology: Great numbers of corn leaf aphids often infest the whorl and underside of leaves of sorghum. This dark, bluish-green aphid is 2 mm long, oval in shape, with black legs, cornicles, and antennae (Color Plate 8). There are winged and

wingless forms. Females without mating give birth to living young. A generation is completed in about seven days.

Symptoms and Damage: The corn leaf aphid most frequently is found deep in the whorl of the middle leaf of preboot sorghum, but also on the underside of leaves, on stems, or in panicles. Adult and nymph corn leaf aphids feed on plant juices but do not inject toxin as do greenbug and yellow sugarcane aphid. The most apparent symptoms from corn leaf aphid feeding is a yellow mottling of leaves when they unfold from the whorl. Sometimes molds grow on the honeydew corn leaf aphids produce in abundance. Honeydew on the panicle can hinder harvest. The aphid also transmits maize dwarf mosaic virus.

Monitoring: When abundant, corn leaf aphids easily are seen within the whorl of sorghum plants. The whorl leaf can be pulled from the plant and unrolled to detect aphids when numbers are low. However, this insect rarely damages sorghum. Consequently, sampling procedures and damage assessment information are not available. In fact, corn leaf aphids are beneficial as a host for the development of natural enemies helpful in suppression of greenbug and other insect pests of sorghum. Because it does not inject toxin as it feeds, the corn leaf aphid rarely causes economic damage. Also, because it prefers to live and feed in the whorl of sorghum, abundance declines rapidly after panicle exsertion (emergence) from the boot. Natural enemies that increase in abundance by feeding on corn leaf aphids remain to feed on other insect pests.

Management: Sorghum plants generally can tolerate many corn leaf aphids without being significantly damaged. Control seldom is justified. Although aphids may be abundant, yield losses rarely occur. Yield losses occur only where corn leaf aphids cause stand loss of seedling plants. Occasionally, corn leaf aphids become so abundant on a

few plants in a field that panicle exsertion and development are hindered. Although this aphid does not need to be controlled, it and other aphid pests can be controlled with organophosphorous insecticides, especially systemic ones.

Greenbug, *Schizaphis graminum* (Rondani)

Description and Biology: Greenbugs are aphids. Both adults and nymphs are light green, with a darker green stripe down the back (Color Plate 9). Adults are pear-shaped and approximately 1.6 mm long. Tips of cornicles and leg segments farthest from the body are black. Winged and wingless forms may be present in the colony. The bluish-green corn leaf aphid should not be confused with greenbug.

Females without mating produce living young (nymphs). Under optimal conditions, nymphs become adults in about seven days. Each female produces about eighty offspring during a twenty-five-day period.

Symptoms and Damage: Greenbug usually is considered a key insect pest of sorghum. The aphid sucks juices from and injects toxin into plants. Small grains, primarily wheat, are the winter host. Where the growing season of wheat does not overlap that of sorghum, grasses such as johnsongrass, are interim hosts.

Greenbugs feed in colonies on the underside of leaves and produce much honeydew. The greenbug may be a pest during the seedling stage of growth but often does not reach damaging numbers until the sorghum panicle develops. Infestations may be detected by the appearance on leaves of reddish spots caused by the toxin greenbugs inject. Reddened areas enlarge as the number of and damage by greenbugs increase. Damaged leaves begin to die, turning yellow and then brown from the outer edges. Damage to seedlings may result in stand loss. Larger sorghum plants tolerate more greenbugs than do seedlings. Yield reductions during boot, flowering, and kernel-

development stages depend on greenbug abundance, length of time greenbugs have infested plants, and plant health. Many greenbugs on booting and older plants reduce yield because of fewer and smaller kernels that develop and weakened plants that may lodge later. Greenbugs also transmit maize dwarf mosaic virus and may predispose sorghum to charcoal rot.

Figure 5 illustrates the economic impact of greenbugs at different abundance levels and plant growth stages. Yield of sorghum is affected economically when there are 500 to 1 000 greenbugs per plant. However, the number of greenbugs required to cause economic damage depends greatly on the size and condition of sorghum plants.

Monitoring: A minimum of forty randomly selected plants should be examined each week in fields 32 ha or smaller in size. In fields larger than 32 ha, or if making a control decision is difficult, examine more than forty plants. Greenbugs seldom are distributed evenly, so plants from all parts of a field should be inspected; avoid examining sorghum plants only along field borders. When making a decision to control greenbug, leaf damage, greenbug abundance, abundance of predators and parasitized greenbugs (mummies), plant size, stage of plant growth, and overall condition of the crop should be determined. It is important to know from week to week whether greenbug abundance is increasing or decreasing and the extent of damage caused by greenbug. For example, insecticide would not be justified if the recommended economic threshold had been reached but greenbug numbers had declined substantially from the previous observation.

Amounts of damage at different sorghum growth stages that would justify insecticide treatment are shown in Table 4. In seedling sorghum (less than 15 cm tall), greenbugs may be found on any part of the plant including in the whorl and, under cool conditions, in the soil at the base of the plant. The entire seedling and soil around the

base of the plant should be examined for greenbugs. The presence of greenbugs and damage to plants (yellowing, death of tissue) should be noted. Greenbugs should be controlled with insecticide when about twenty percent of seedlings are infested, but before any plants are killed. Greenbugs should be controlled when twenty percent of larger plants to boot stage have red spots or yellowing, but before any full-sized leaves are killed. Greenbugs on boot- to heading-stage sorghum should be controlled when leaves have red spots or yellowing and one full-sized leaf per plant is dying. After sorghum flowering and before the hard-dough stage, greenbugs should be controlled before they kill more than two full-sized leaves on twenty percent of plants. When estimating leaf damage, consider any leaf to be dead when more than seventy-five percent of its surface is red, yellow, or brown. Injury by greenbugs should not be mistaken for the natural senescence of small, bottom "seed" leaves. Estimate average leaf damage for the entire field unless it is feasible to spot treat.

These guidelines are based on the assumption that greenbug abundance is increasing so rapidly that control by beneficial insects is not effective. Also, plants undergoing drought or other stress cannot tolerate as many greenbugs without suffering reductions in yield. However, when more than twenty percent of greenbugs are brown and swollen from being parasitized, insecticide usually is not necessary.

Management: Greenbug abundance in a field can increase twenty-fold per week, but the seasonal average is five- to six-fold each week. Rainfall and predators suppress increase in greenbug abundance early in the season, although abundance of natural enemies has a lag time of one to two weeks. The parasite, *Lysiphlebus testaceipes* (Cresson), usually is responsible for rapid decline in aphid abundance late in the season.

Sorghum hybrids resistant to greenbug should be used. However, four greenbug biotypes, C, E, I, and K, are capable of infesting sorghum. Biotypes do not differ in appearance but in how they injure resistant hybrids. Greenbug biotypes E and I currently are most common and may occur together in some sorghum-growing areas. Biotype I greenbugs damage sorghums resistant to biotype E, but biotype I-resistant hybrids are resistant to biotype E. Resistant hybrids will not be free of greenbugs, but are infested with fewer greenbugs and better tolerate damage than do susceptible hybrids. Economic threshold levels for resistant hybrids are the same as for susceptible hybrids because thresholds for both kinds of sorghum are based on amount of plant damage.

Greenbug can be controlled by some organophosphorous insecticides but is resistant to several. Most naturally-occurring parasites and predators will be spared if extremely low dosage rates of organophosphates are used to control greenbug when abundance reaches the economic threshold. Some systemic insecticides applied to seed or in-furrow at planting control greenbugs.

Whorl-Infesting Caterpillars

Corn earworm and fall armyworm infest whorls of sorghum plants but usually are more injurious as panicle pests. Consequently, these insects are discussed in the section on panicle-feeding insect pests.

Banks Grass Mite, *Oligonychus pratensis* (Banks)

Description and Biology: Spider mites, especially Banks grass mite and less frequently twospotted spider mite, *Tetranychus urticae* Koch, infest sorghum and many species of grasses. Spider mites are more common on sorghum grown in arid areas. Female spider mites, with a body length of 0.40 to 0.45 mm, are larger than males. After feeding, both sexes usually become green, with the exception of the palpi and first two pairs of legs that

remain light salmon colored (Color Plate 10). Two dark spots, comprised of food contents, show through the transparent body wall. Eggs (about fifty per female) are laid in webbing on the underside of leaves. Eggs are pearly white, spherical, and one-fourth the size of the female. Eggs hatch in three to four days. Six-legged nymphs are light green; older eight-legged nymphs are darker green. The life cycle under good conditions requires about eleven days.

Symptoms and Damage: Spider mites suck juices from the underside of sorghum leaves, beginning along the midrib of lower leaves. Infested areas of leaves are pale yellow on the top surface and later become reddish. Leaves may die. Spider mites when abundant spread up the plant. The underside of infested leaves has a deposit of fine webbing spun by the spider mites. Spider mites when abundant may invade and web sorghum panicles. Increase in spider mite abundance usually occurs after sorghum panicles emerge. Large numbers of spider mites before the hard-dough stage reduce the ability of sorghum plants to make and fill kernels. However, yield loss may occur after the hard-dough stage if spider mites are abundant enough to cause lodging and related harvest losses. Figure 6 illustrates the economic impact of spider mites at different infestation levels.

Monitoring: Spider mites infesting sorghum are extremely small. The underside of lower leaves should be inspected carefully. Spider mites occur in colonies, first along the midrib of leaves, but later spread away from the midrib and up the plant to higher leaves. Webbing is evidence of the presence of spider mites. It is common for spider mite infestations to begin along field borders, but an infestation quickly will spread throughout a field.

Hot and dry weather usually favors rapid increase in spider mite abundance. Also, spider mites in sorghum often respond as induced (secondary) pests following insecticide application for key insect pests such as greenbug. Rapid increase in spider mite abundance following insecticide application is thought to be caused by tolerance to some insecticides, destruction of beneficial insects and mites, and dispersal of spider mites from colonies.

Management: Control of spider mites by natural enemies is not always effective. Because spider mites increase more rapidly on moisture-stressed plants, irrigation, where available, should be applied to prevent plant stress. Spider mites may move from small grains, especially wheat, to sorghum. Not planting sorghum next to wheat avoids direct infestation by spider mites. Insecticide is justified when one-third of the leaves of most sorghum plants in a field are infested with mites. Thorough coverage with the spray mixture is required. At least 28 to 47 liters of spray mixture should be applied per hectare. Insecticides may not provide effective control because spider mites often are resistant. Every effort should be made to control spider mites with the first insecticide application, because subsequent applications usually are ineffective.

Insect Pests of Panicles

The most important insect pests infesting sorghum panicles and developing kernels are sorghum midge, caterpillars, and panicle-feeding bugs.

Sorghum Midge, *Stenodiplosis sorghicola* (Coquillett)

Description and Biology: The sorghum midge probably is the most widely distributed of all sorghum insect pests and one of the most damaging in the southern United States. It occurs in almost all regions of the world where the crop is grown, except Southeast Asia. The adult sorghum midge is a 1.3-mm-long, fragile-looking, orange-red fly, with a yellow

head, brown antennae and legs, and gray membranous wings (Color Plate 11). During the single day of adult life, each female lays about 50 yellowish-white eggs between the glumes of flowering spikelets of sorghum. The cylindrical eggs are 0.1 to 0.4 mm long and hatch in two to three days. Initially, larvae are colorless, but, when fully grown, are dark orange. Larvae complete development in nine to eleven days and pupate between the glumes of the spikelet. Shortly before adult emergence, the pupa moves upward until three-fourths the pupa protrudes between the glumes at the tip of the spikelet. After the adult has emerged, the clear pupal skin remains at the tip of the spikelet. The pupal period lasts three days. A generation is completed in fourteen to sixteen days. The insect's rapid development permits multiple generations during a season and results in high infestation levels when sorghum flowering is extended by a range of planting dates or sorghum maturities. Sorghum midge diapause to overwinter as larvae in cocoons in spikelets of host grasses that, in the United States, are exclusively sorghum and johnsongrass. When plants are shredded or spikelets shed, spikelets fall to the ground and are disked into or covered with the soil. Sorghum midges that emerge during the spring infest johnsongrass before flowering sorghum is available. The insect increases in abundance during the season, especially if flowering sorghum continues to be available. Sorghum midge abundance declines late in the season.

Symptoms and Damage: Sorghum midge larvae feed on the newly-fertilized ovary, preventing kernel development and causing direct grain loss. Glumes of a sorghum midge-infested spikelet fit tightly together because no kernel develops. Typically, a sorghum panicle infested by sorghum midge will have, depending on the degree of damage, various proportions of normal kernels scattered among nonkernel-bearing spikelets.

The economic impact of different abundance levels of sorghum midge infesting resistant and susceptible sorghum hybrids is shown in Figure 7. In1998 economics, a $10 insecticide application would be justified when there was about one sorghum midge per panicle of susceptible sorghum or about five sorghum midges per panicle of resistant sorghum.

Monitoring: Abundance of sorghum midge adults must be assessed. To do so, fields should be inspected at midmorning when the temperature reaches approximately 28 C, when sorghum midge adults are most abundant on flowering sorghum panicles. Because adult sorghum midge live less than one day, a new brood is present each day. Sorghum midge abundance should be monitored almost daily during panicle flowering. Sorghum midge adults crawl on or fly about flowering panicles. The easiest and most efficient way to detect and count sorghum midge is carefully inspecting of all sides of randomly-selected flowering panicles. Panicles should be handled carefully to avoid disturbing ovipositing sorghum midges. Other methods, such as placing a clear plastic bag or jar over the panicle as a trapping device, can be used.

Because they are weak fliers and rely on wind currents to aid their dispersal, adult sorghum midge usually are most abundant along borders of sorghum fields. For this reason, plants first should be inspected along field borders, particularly fields downwind of earlier flowering sorghum or johnsongrass. If few sorghum midges are on sorghum panicles along field borders, there is little need to sample the entire field. However, if sorghum midge numbers along field borders equal or exceed the economic threshold level, additional panicles from the entire field (avoiding plants within 45 m of field borders) should be inspected. Average sorghum midge abundance should be calculated based on

these additional samples. At least twenty panicles should be sampled for each 8 ha in the field.

Management: Effective management of sorghum midge requires integration of practices to avoid or reduce abundance. Early and uniform planting of sorghum in a locale is the most effective cultural management method. Planting hybrids with uniform maturity early prevents late flowering and avoids damaging infestations. Cultural practices that promote uniform panicle exsertion and flowering in a field also are important in sorghum midge management, in making treatment decisions, and in achieving acceptable levels of insecticidal control. Using cultivation or herbicides to eliminate johnsongrass inside and outside the field also helps suppress sorghum midge abundance. Deep plowing sorghum residues kills some overwintering larvae, reducing sorghum midge abundance the next year.

Sorghum midge-resistant hybrids, within limits, provide an additional management tool. At similar infestation levels of sorghum midge females, resistant hybrids are only one-fifth as damaged as susceptible hybrids, meaning that resistant hybrids have economic injury levels five times higher than susceptible hybrids.

Multiple insecticide applications directed at sorghum midge adults prevent damage when sorghum is planted too late to escape damaging infestations. To determine the need for chemical control, crop development, yield potential, and sorghum midge abundance should be assessed daily during sorghum flowering. Because sorghum midge lay eggs in flowering sorghum spikelets (yellow anthers exposed), damage can be caused until all spikelets on a panicle or all plants in a field have flowered. The period of susceptibility to sorghum midge may last from seven to nine days (individual panicle) to two to three weeks (individual field), depending on uniformity of flowering. Peak flowering

of panicles in a field occurs on the eighth day of flowering, when 19.2 percent of the sorghum in a field is flowering (Figure 8).

Need for insecticide is based on the number of adult sorghum midge per panicle during the flowering period. Economic injury levels for susceptible and resistant sorghum hybrids are presented in Table 5. If adults still are present three to five days after the first applications of insecticide, immediately apply insecticide again. Several insecticide applications at three-day intervals may be justified if sorghum midges are abundant.

Corn Earworm, *Helicoverpa zea* (Boddie)

Description and Biology: Moths are 19 mm long, with a wing span of 38 mm. They vary in color from dusty yellow to reddish brown. Females are active in the evening and live about twelve days. Each female may deposit 350 to 3 000 eggs. Eggs are flattened spheres, prominently ribbed, and 1.2 mm in diameter. They are white when deposited but soon darken and hatch in three to five days. White, newly-hatched larvae grow rapidly and are variously colored, ranging from pink, green, or yellow, to almost black (Color Plate 12). Many are conspicuously striped. Down the side is a pale stripe edged above by a dark stripe. A dark stripe divided by a narrow white line that makes the dark stripe appear doubled is down the middle of the back of larger larvae. Fully- grown larvae are robust and 38 to 50 mm long. The pupa is in the soil and is the overwintering stage.

Symptoms and Damage: Corn earworms infest both whorls and panicles of sorghum. Infestation of panicles is more serious than infestation of whorls.

Larvae that hatch from eggs laid on sorghum leaves before panicles are available migrate to feed on tender, folded leaves in the whorl. When damaged leaves unfold, they are ragged with "shot holes." Although this may look dramatic, damage to leaves usually does not affect yield, and larvae usually do not need to be controlled during the whorl

stage of sorghum growth. Insecticide may be justified economically if larval feeding reduces leaf area by about thirty percent or damages developing panicles or growing points within the whorls.

Infestation of sorghum panicles is of concern because corn earworm larvae feed on developing kernels. Small larvae at first feed on florets, then hollow out kernels. Later-instar larvae completely destroy maturing kernels. About eighty percent of damage is caused by larvae of the last two instars. Larval excrement or frass is common in infested panicles and may be seen on the tops of upper leaves or on the ground under plants. Under certain conditions, kernels of infested panicles may mold. Figure 9 illustrates the economic impact of corn earworm at different abundance levels. Based on today's prices, one or two larvae per panicle would justify a $10 insecticide application. Table 6 shows economic threshold levels for corn earworm.

Monitoring: Sampling for corn earworm in sorghum whorls requires different procedures than when larvae are in panicles. Holes in leaves as they unroll from the whorl are evidence of infestation by corn earworm. The whorl leaf must be pulled from the plant and unfolded to find the larva. The whorl of an infested plant contains frass produced by a larva as it feeds. Because of cannibalism, there usually is only one corn earworm larva per plant whorl.

Inspection of sorghum panicles should begin when flowering starts and continue at five-day intervals until hard dough. To find corn earworm larvae, randomly selected sorghum panicles should be shaken vigorously into a 19-liter bucket. Larvae easily can be counted in the bucket. This "beat-bucket" technique permits detection of even small larvae (less than 6 mm long) commonly overlooked. At least thirty panicles for each 32 ha should be inspected.

Management: Natural mortality, predators, parasites, pathogens, and cannibalism among larvae suppress abundance of corn earworms in sorghum whorls and panicles. Infestations usually are less in early- than later-planted sorghum. Whorl infestation by corn earworm usually is not severe enough to justify insecticide. Also, corn earworms within the whorl of sorghum are protected from insecticide. An important management tactic is to use hybrids with loose or open panicles. Natural mortality of early-instar larvae is high. Two corn earworms about 13 mm long or one longer than 13 mm per panicle are enough to justify insecticide. Although larger larvae are more difficult to control with insecticide, corn earworms in sorghum usually are controlled more easily than in cotton.

Fall Armyworm, *Spodoptera frugiperda* (J. E. Smith)

Description and Biology: Young larvae are greenish with black heads. Mature larvae vary from greenish to grayish brown and have a light-colored, inverted, Y-shaped suture on the front of the head, and dorsal lines lengthwise on the body (Color Plate 13). The moth has variegated-gray front wings. Eggs in masses covered with scales and hair of the moth are deposited on the underside of leaves or in panicles. The insect requires about a month to complete a generation. Diapause is not common in the United States, and adults migrate from subtropical and tropical America northward each year as the temperature warms.

Symptoms and Damage: As do corn earworms, fall armyworms infest both the whorl and panicle of sorghum. Fall armyworms sometimes infest the whorl and feed on tender leaf tissue of young sorghum plants. When leaves unfold, irregular, elongated feeding areas or rows of holes are visible. Although rare, larvae may feed on panicles not yet emerged from the whorl. To locate larvae, the whorl leaf must be pull from the plant and unfolded. Frass is present where the larvae feed within the whorl.

Fall armyworms infest panicles after panicles emerge. Panicle infestation by fall armyworms is similar to that by corn earworms, except fall armyworms are not cannibalistic. Young, small larvae feed first on florets. As larvae grow, they feed on developing kernels. Most damage to kernels is caused by larger larvae and, as with corn earworm, about eighty percent of damage is by the last two larval instars. Frass and molds are common in infested panicles. The economic impact of fall armyworm at different abundance levels is the same as for corn earworm (Figure 9), as are the economic threshold levels (Table 6).

Monitoring: Sampling techniques for fall armyworm are the same as those provided for corn earworm.

Management: Several wasps and flies parasitize, several bugs and beetles prey, and pathogens, especially fungi, infect and kill fall armyworm larvae. Planting early is an important management tactic to escape infestation. Insecticide may be justified if feeding damages about thirty percent of leaf tissue or the developing panicle, although this situation seldom occurs. Using sorghum hybrids with loose panicles is an effective management practice. Insecticide usually is justified when there is an average of two larvae less than 25 mm long or one larva longer than 25 mm per panicle.

Sorghum Webworm, *Nola sorghiella* Riley

Description and Biology: The sorghum webworm is an occasional pest of panicles of late-planted sorghum. This insect pest occurs primarily in humid areas. The adult is a small, white moth with a wingspan of about 13 mm. Moths are active at night, laying about one hundred eggs singly but rather securely fastened to flowering parts or kernels of sorghum. Eggs (0.5 mm in diameter and 0.25 mm in height) are round to oval in outline and flattened. They are white at first but turn deep yellow to brown before hatching in three to

four days. Larvae are flattened, yellowish or greenish brown, and marked with four longitudinal reddish to black dorsal stripes. Larvae are about 13 mm long when mature and covered with spines and hair (Color Plate 14). The larval stage lasts thirteen days. The pupa, within a cocoon, is reddish brown, slender, and subcylindrical. The pupal stage lasts six days, and adults live about five days. A generation requires one month. There may be as many as six generations a year. Sorghum webworms diapause as larvae hidden on the host plant.

Symptoms and Damage: Large numbers of sorghum webworms may be found in panicles, especially of late-planted sorghum. Young larvae feed on developing florets. Older larvae gnaw circular holes in and feed on the starchy contents of maturing kernels, which usually are only partly consumed. Each larva may consume more than twelve kernels in twenty-four hours. Larvae do not spin webs (as the name might imply) in the panicle but, when disturbed, young larvae often suspend themselves from thin silken threads.

Monitoring: Panicles beginning to flower should be inspected at five-day intervals until kernels are in the hard-dough stage. To find sorghum webworms, shake panicles vigorously into a 19-liter bucket. Even small larvae easily can be counted in the bucket. At least thirty plants from each 32 ha of field should be inspected.

Management: Cultural controls include plowing crop residues to destroy overwintering larvae, planting early, and using sorghum with open panicles. Insecticide applications are economically justified when there is an average of five or more small larvae per panicle (Figure 10).

Panicle-Feeding Bugs: Rice Stink Bug, *Oebalus pugnax* (Fabricius); Southern Green Stink Bug, *Nezara viridula* (L.); Conchuela, *Chlorochroa ligata* (Say);

Leaffooted Bug, *Leptoglossus phyllopus* (L.); False Chinch Bug, *Nysius raphanus* Howard

Description and Biology: Several species of true bugs, primarily stink bugs, may move in large numbers from cultivated and noncultivated host plants to sorghum during kernel development. The bugs usually are clumped in a field.

The rice stink bug is a common stink bug infesting sorghum. Adults are straw-colored, shield-shaped, and 12 mm long (Color Plate 15). The insect overwinters in the adult stage in grass. Ten to forty-seven light-green, short, cylindrical eggs are laid in a cluster of two rows. Eggs hatch after five days. Nymphs require fifteen to twenty-eight days to become adults. The rice stink bug has many hosts, but prefers grasses.

The southern green stink bug is green, 19 mm long, and mostly shield-shaped (Color Plate 16). Females deposit 300 to 500 eggs in clusters of thirty. The eggs hatch in about seven days, and the adult stage is reached in about six weeks. Generations occur at five- to six-week intervals and there are three to five generations per year. Adults live forty to sixty days or overwinter protected under litter, bark, or other plant materials.

The conchuela is a stink bug that varies in color from dull olive to ash gray and is about 20 mm long (Color Plate 17). The most characteristic markings are orange-red bands along the lateral margins of the thorax and wings and a spot of the same color on the back at the base of the wings.

The leaffooted bug is brown, about 20 mm long, and oblong (Color Plate 18). A white band extends across the front wings. The tibiae of the hind legs are dilated or leaf-like. Eggs are laid in flattened rows of fifteen to thirty-five. Nymphs are reddish.

The false chinch bug is uniformly gray to brown and about 3 mm long (Color Plate 19). The insect occasionally migrates in large numbers from wild hosts to sorghum, but infestations usually are concentrated in small areas of the field.

Symptoms and Damage: The bug species described above have similar natures and symptoms of damage. These bugs suck juices from developing sorghum kernels and, to a lesser extent, from other panicle parts. They may cause economic damage, depending on the number of bugs per panicle, duration of the infestation, and stage of kernel development when infestation occurs. The number of bugs that will reduce grain yield varies according to species and stage of kernel development when infestation occurs. Bugs cause more damage during early kernel development and less damage as kernels develop to the hard-dough stage. Both nymphs and adults reduce kernel weight, size, and quality. Fungi often infect and cause damaged kernels blacken and deteriorate. Damaged kernels rarely develop fully and may be lost during harvest with mechanized equipment. Figures 11 to15 illustrate economic impacts of panicle-feeding bugs at different abundance levels and stages of kernel development.

Monitoring: Accurately estimating the number of panicle-feeding bugs per plant is influenced by the tendency of bugs to congregate on sorghum panicles and in areas of a field. The beat-bucket technique described for monitoring corn earworm can be used to estimate the average number of bugs per panicle. However, adult bugs will fly from the sampled plant and from the bucket. Plant leaves and weeds in the field also should be inspected for bugs. At least thirty plants from each 32 ha of field should be inspected.

Management: Infestation in sorghum usually occurs when other hosts become unacceptable or unavailable. Sorghum planted early is more likely to avoid bugs migrating

from other hosts. Not all species of stink bugs in sorghum cause economic damage. Several species prey on harmful insects and, thus, are beneficial.

Sorghum kernels in the hard-dough stage usually are not damaged by bugs. For most species, an infestation of sixteen or more bugs per panicle at the hard-dough stage of kernel development is required to justify insecticide. The economic injury level for rice stink bug ranges from four to nine and five to thirteen at the milk and soft-dough stages, respectively (Table 7). Insecticide would be justified when there are two to six or four to eleven southern green stink bug, conhuela, or leaffooted bug per panicle at the milk and soft-dough stages of kernel development, respectively (Table 8). The economic injury level is 140 false chinch bugs per panicle when infestations begin at the milk stage of kernel development.

Stalk Borers: Sugarcane Borer, *Diatraea saccharalis* (Fabricius); Neotropical Borer, *D. lineolata* (Walker); Southwestern Corn Borer, *D. grandiosella* Dyar

Description and Biology: Sorghum in the United States usually is not seriously infested by stalk borers. However, stalk borers are often key insect pests of sorghum in other areas of the world. Larvae of stalk borer species resemble each other in appearance and have similar biologies. A fully-grown larva is about 25 mm long, with a brown head and thorax, and white- to yellow-colored body (Color Plate 20). Most body segments have conspicuous round, brown or black spots. Spots are lighter colored or absent on mature, overwintering larvae. The insects pass the winter as fully-grown larvae in cells inside stalks or root crowns that remain after the crop is harvested. Larvae pupate in the spring, and adults emerge a few weeks later. The buff-colored moths lay clusters of elliptical to oval-shaped, flattened eggs that overlap like fish scales or shingles on leaves of host

plants. Eggs hatch in three to seven days. The larval stage lasts about twenty-five days and the pupal stage about ten. There are one to three generations a year.

Symptoms and Damage: Young larvae feed for a few days on leaves or the leaf axis. Older larvae tunnel into and bore up and down the pith of the stalk. Borer-infested stalks are smaller in diameter, and may lodge. Boring by larvae often causes the peduncle to break and panicle to fall. Injury by borers makes the plant more susceptible to stalk rot pathogens.

Monitoring: Determining the presence of stalk borers requires careful examination of sorghum plants. A small hole near the leaf axis indicates a larva entered the stalk. Stalks must be split to see the larvae. Eggs on the leaves are difficult to find. Clusters containing twelve to twenty small, individual eggs may be on the top or underside of leaves, depending on the borer species. Abundance of eggs and small larvae must be assessed and insecticide applied before larvae bore into stalks.

Management: Planting sorghum early is an important management tactic. Plowing to break stubble and bury crop residues soon after harvest destroys overwintering larvae by exposing them to cold temperatures. Chemical control rarely is justified.

Mexican Rice Borer, *Eoreuma loftini* (Dyar)

Description and Biology: The Mexican rice borer is a stalk-boring insect that recently invaded the United States from Mexico. It has the potential to become an important insect pest of sorghum, but has not done so yet. The creamy-white, 12- to 19-mm-long moth has enlarged mouthparts that protrude in front of the head. This nocturnal moth has a dark spot in the center of each front wing. The cream-colored larva has an orange-brown head and two broken, purple-red lines on each side along the length of the body. Unlike many

other borer species, the Mexican rice borer has no conspicuous hairy plates on the dorsal surface of the body.

Masses of five to 100 cream-colored, globular eggs are cemented between layers of dry leaf tissue. Moths prefer to lay eggs hidden on dry leaf material close to the ground but also on upper green parts of the plant. The mature larva, 19 to 25 mm long, chews a pupal chamber toward the outer edge within the stalk. The pupa is 19 to 22 mm long, orange-brown, with small projections (tubercles) toward the posterior of the abdomen. The moth emerges through a "window" of one to two layers of leaf tissue that cover the pupal chamber within the stalk. Each generation is completed in forty-five to fifty days under warm conditions.

Symptoms and Damage: Newly-hatched larvae move to feeding sites on leaf blades or sheaths to chew into soft tissue inside the sheath that wraps around the stalk. Tunneling within the leaf sheath produces a mine, with small perforations and dramatic discoloration of tissue. Larvae feed in leaf sheaths for several weeks before boring into the stalk. They usually directly enter the stalk by chewing into the internode adjacent to the leaf sheath on which they were feeding. Most tunneling occurs near the outer surface of the stalk adjacent to the rind. Tunnels may be vertical, typical of most borers, but also may be horizontal or diagonal within the stalk. Mexican rice borer tunnels are filled with frass and, thus, differ from tunnels of other stalk borers that periodically remove frass. Larval feeding near the growing point of the plant early in the season causes "deadheart". Some young plants may die, but usually there is compensation from tillering. Moths lay eggs on deadhearts when other dry leaf material is not available.

Feeding on the leaf sheath disrupts normal leaf function. Feeding causes the leaf sheath to turn dark purple, often the first evidence of infestation. This symptom should be monitored. Damaged leaves often die, reducing plant productivity.

Larval tunneling within the stalk damages the vascular system that moves water and nutrients within the plant. Stalk damage can result in incomplete panicle filling or aborted development. Tunnel openings allow fungi to invade the plant. Reddish discoloration caused by a fungus usually is seen in the pith of the damaged internode. Decomposition and structural damage to the stalk cause plant lodging. Plants with stalk damage often break or lodge during harvesting. Tillers and post-harvest regrowth are susceptible throughout the year to attack by Mexican rice borer larvae.

Management: Plowing debris before planting and maintaining healthy plants early in the season reduce the amount of dry leaf material available for oviposition and thus postpone infestation by Mexican rice borer. Damage is minimial when sorghum is planted and matures at a normal time.

Insecticide should be applied to control young larvae feeding in leaf sheaths. Larvae within stalks are protected and unlikely to come into contact with foliar insecticide.

Sugarcane Rootstock Weevil, *Anacentrinus deplanatus* (Casey)

Description and Biology: The adult is a dark brown or black weevil about 9 mm long and 2.5 mm wide. The insect overwinters as an adult protected by plant residues on the ground. Weevils infest wild grasses during early spring and later move to sorghum. The female uses her mouthparts to make a small puncture in the plant into which the egg is deposited and the hole then sealed by a substance. Eggs are creamy white, oval, 0.25 mm in diameter, and 0.5 mm long. Each female lays about sixteen eggs that hatch in six days. Larvae are white, legless grubs about 5 mm long when fully grown. Pupae are

white until shortly after emergence, when they become brownish. Larvae and pupae develop in twenty-five and ten days, respectively. A generation is completed in forty-one days.

Symptoms and Damage: Adult weevils feed on young sorghum plants and rootstocks. This damage is noticeable but not as serious as that caused by larvae. Larvae tunnel into the sorghum stalk below or just above the surface of the soil. Tunnels, except being smaller, resemble those made by other borers. Larvae often are found at nodes and near the outer surface of the stalk. Their feeding often is responsible for the drought-stressed appearance and lodging of sorghum plants. Exit holes and feeding tunnels allow pathogens such as charcoal rot to enter the plant.

Monitoring and Management: Sugarcane rootstock weevil sporadically infests sorghum, especially during dry years. Good cultural practices that promote early and vigorous plant development are beneficial against this insect. However, effective insecticides and application techniques are not available.

Insect Pests of Stored Sorghum Grain

Beetles and moths are the most important insect pests of stored sorghum grain. Most of these insects have short developmental times, high rates of reproduction, and long lives. Most damage is done by larvae. Damage by and control of these insects can be expensive.

Primary and Secondary Insect Pests

Insects that attack stored sorghum grain are either primary pests that attack whole kernels and develop inside the kernel, or secondary pests that feed primarily on cracked or broken kernels, grain dust, or molds that grow on grain in storage. These insects consume and directly damage grain, or cause indirect damage by contamination with

feces, odors, webbing, cast skins, or dead insects. Indirect damage also can be by insect-caused heating and moisture accumulation, with subsequent molding and caking of grain.

Grain Weevils: Rice Weevil, *Sitophilus oryzae* (L.); Maize Weevil, S. *zeamais* Motschulsky; Granary Weevil, *S. granarius* (L.)

Description and Biology: Weevils are the primary and most destructive insect pests worldwide of stored sorghum grain, especially in warm, humid countries. Adult rice and maize weevils are reddish brown, about 4 mm long (maize weevil is slightly larger), and have four light reddish or yellowish spots on their wings. Weevils infest grain in the field and in storage. The adult female bores a hole into a kernel, deposits an egg, and covers it with a gelatinous substance. A female lays 300 to 500 eggs during the four to five months of her life. Eggs hatch in three days. Larva are legless, short, stout, and whitish with a brown head, and mature in three to six days. There may be five to seven generations a year. The granary weevil prefers temperate climates. Also, it lacks reddish or yellowish spots on the wing covers, and adults cannot fly.

Grain Borers: Lesser Grain Borer, *Rhyzopertha dominica* (Fabricius)

Description and Biology: This primary insect pest is a cosmopolitan beetle about 4 mm long, slender, cylindrical, shiny dark brown or black, with a rough wing surface. The head is turned down and covered by a hood-shaped thorax. Adults lay 300 to 500 eggs singly or in clusters on grain or in grain powder. Eggs hatch in five to eleven days into fleshy grubs that appear swollen at the extremities. Grubs bore into and feed inside grains. The larval period lasts twenty-five to fifty days, depending on temperature. Pupation occurs within the grain or in grain dust. The pupal period lasts seven to eight days. A life cycle may require two months, and there are three to four generations a year.

Grain Moths: Angoumois Grain Moth, *Sitotroga cerealella* (Olivier)

Description and Biology: This cosmopolitan insect is an important primary pest of stored sorghum. The moth is buff or yellowish-brown with a wing span of about 13 mm. The hind wings have a heavy fringe of hairs longer than the wing width. Adults do not feed on grain. The female lays as many as 400 eggs indiscriminately on or between kernels on panicles in the field or grain in storage. The egg is oval and white, but turns bright red and hatches within a week. The tiny larva crawls about searching for a weak spot through which to enter a kernel and feed on the internal contents. The larval period is two to three weeks. The moth emerges about a week after pupating.

Grain Beetles: Flat Grain Beetle, *Cryptolestes pusillus* (Schnherr); Rusty Grain Beetle, *C. ferrugineus* (Stephens)

Description and Biology: The flat grain beetle and rusty grain beetle are secondary pests, widely distributed, and among the smallest (1.5 mm long) beetles found in stored grain. They are flat, oblong, reddish brown beetles with antennae about two-thirds the length of the body. Small white eggs are deposited loosely or in crevices in the grain. Larvae remove only the germ from infested kernels, but also feed on dead insects. Larvae form cocoons of a gelatinous substance to which food particles adhere, and then transform to the pupal stage. Grain beetles develop from eggs to adults in five to nine weeks, depending on temperature.

Flour Beetles: Red Flour Beetle, *Tribolium castaneum* (Herbst); Confused Flour Beetle, *T. confusum* (Jacquelin du Val); Sawtoothed Grain Beetle, *Oryzaephilus surinamenis* (Linnaeus); Merchant Grain Beetle, *O. mercator* (Fauvel)

The red flour beetle and confused flour beetle are cosmopolitan, secondary pests of stored grain. Adult beetles are 3 to 4 mm long, flattened, oblong, and chestnut brown.

The head and upper parts of the thorax of the confused flour beetle are covered with minute punctures. The wing covers are ridged lengthwise and sparsely punctured between the ridges. Adults lay 450 minute, cylindrical, white eggs covered with a sticky secretion that becomes covered with flour or meal. Eggs hatch in five to twelve days. The yellowish-white, cylindrical grub is covered with fine hairs and is fully grown in twenty-seven to twenty-nine days. The pupa has no pupal case. Adults emerge in three to seven days. Depending on weather conditions, there may be four to seven generations a year, a generation developing in one to four months. Optimal conditions for development are 35^{o} C and seventy percent relative humidity.

The sawtoothed grain beetle is a secondary stored grain pest. The adult is a slender, flat, brown beetle about 2.5 mm long. The thorax has six sawtooth-like projections on each side. The merchant grain beetle is a related species often confused with the sawtoothed grain beetle. Both species have similar biologies.

Flour Moths: Rice Moth, *Corcyra cephalonica* (Stainton); Indian Meal Moth, *Plodia interpunctella* (Hubner)

Description and Biology: The rice moth is an economically important secondary pest of stored sorghum. The adult moth is pale grayish brown, with a wing span of 14 to 24 mm; the head has a projecting tuft of scales. Adults are short lived. Females lay as many as 200 spherical, white eggs that hatch in three to five days. Larvae are creamy white and use silken threads to web together particles of food and frass into galleries in which they live and feed. The larval period is twenty to thirty days, and the pupal period lasts nine to ten days.

The Indian meal moth is a widely distributed secondary insect pest. The adult has a wing span of 18 mm. Peculiar forewing markings of reddish brown with a copper luster

on the outer two-thirds and whitish gray on the inner one-third easily distinguish this moth from other grain pests. A female may lay as many as 500 eggs. Development from egg to adult requires twenty-six days.

Other Stored Grain Pests

Many other species of insects and a few mites are found in stored sorghum grain. For the most part, their presence depends on the presence of grain dust, foreign materials, or grain molds. Psocids, grain mites, and the hairy fungus beetle, *Typhaea stercorea* (L.), are examples of other pests found in stored sorghum grain. The presence of these insects is indicative of grain in poor condition.

Monitoring: Stored sorghum grain should be examined regularly to detect early infestations of insects so they can be controlled before extensive damage occurs. During cool times of the year, grain should be checked every four to six weeks, but during warm seasons, grain should be checked every two to four weeks. A systematic sampling procedure using a grain probe should be used. The probe should be inserted horizontally 5 cm under the grain surface in the center of the bin where the grain surface has not been disturbed. Additional samples should be collected from the sides of the bin. Samples should be taken no farther than 6 m apart. After sampling the grain near the surface, the probe should be inserted into the grain mass from top to bottom. Each sample of grain should be placed in a tray long enough to accommodate the grain probe and examined for insects. Sieves designed for sorghum grain aid in examining for insects.

Pheromone-baited sticky traps can be used to monitor for stored grain moths. A grain probe trap will detect most insects infesting stored sorghum grain. This trap is a plastic probe about 37.5 cm long that functions as a pitfall trap for grain beetles and their larvae. Two to four grain probe traps placed into the surface of grain during a forty-eight-

hour period will trap insects. Collection of ten or more insects per probe during a twenty-four-hour period is cause for concern. Using the regular grain probe, one primary pest beetle per quart of grain is a damaging infestation. Five secondary insect pests per quart of grain are damaging.

Management: Stored grain insect pests can be managed by sanitation, well-constructed and maintained bins, residual insecticides applied to the bin and grain, and fumigants. Granaries should have no leaks that allow moisture or insects to enter, no double walls or floors, and no places for old grain to accumulate. Old grain should not be allowed to accumulate. Grain should be dried below twelve percent moisture content. Granaries should be treated with residual insecticide before storing new grain. Insecticide can be applied directly to the grain surface. Grain also may be fumigated.

Beneficial Insects

Natural enemies of sorghum insect pests include ladybird beetles, family Coccinellidae; syrphid flies, family Syrphidae; lacewings, family Chrysopidae; ground beetles, family Carabidae; predaceous bugs, families Anthocoridae, Nabidae, and Lygaeidae; spiders; and several species of parasitoids, families Braconidae, Ichneumonidae, Chalcidae, and Tachinidae. It is not practical to present lengthy discussions of all natural enemies of sorghum insect pests, but some natural enemies are described briefly. Conservation of natural enemies is important in managing sorghum insect pests.

Ladybird Beetles: Several species including Convergent Lady Beetle, *Hippodamia convergens* (Guerin-Meneville); Scymnus Lady Beetle, *Scymnus loewii* (Mulsant)

Description and Biology: Convergent and scymnus lady beetles are two common species in sorghum. Adult ladybird beetles are hemispherical in shape. Depending on the species, lady beetles vary in length from 1.5 to 6.0 mm, may be orange, red, tan, brown,

gray, or black and spotted or marked with contrasting colors of red, yellow, black, or white. Ladybird beetles sometimes are confused with leaf beetles. Larval ladybird beetles are elongated and tapered posteriorly. Their bodies are dark with bright markings and covered with spines. Larvae of scymnus lady beetles are covered with long streamers of white wax.

Ladybird beetles hibernate as adults, often in large numbers, in protected and dry places. Females lay clusters of 200 to 1 000 yellow eggs that hatch in three to four days. Scymnus lady beetles lay eggs singly. Larvae feed for two to three weeks. Adults and larvae prey primarily on aphids but also feed on spider mites, insect eggs, and small larvae of sorghum insect pests.

Syrphid Flies: Several species, family Syrphidae

Description and Biology: Adults of this large group of flies are flower, hover, or sweat flies. Adults feed on nectar and pollen of flowers, and pollinate plants. Many are brightly colored and resemble bees or wasps. Most species hover motionless except for beating their wings; others fly with a buzzing sound like bees.

Syrphid fly larvae, as a group, vary considerably in appearance and biology. They are 6 to 19 mm long, elongate, legless, and slug-like. Their bodies are pointed at the head, blunt or broad at the tail end, and somewhat depressed. Many are yellow, pink, green, or brown marked with black or white.

The larvae are common among aphid colonies and move slowly over surfaces of plants, using their pointed jaws to grab aphids and suck out the body contents before discarding the aphid skins. Syrphid fly larvae can consume one aphid per minute. Adults lay glistening white, elongated eggs among colonies of aphids.

Green Lacewings: *Chrysoperla* spp.; C*hrysopa* spp.

Description and Biology: Lacewing larvae, called aphis lions, feed voraciously on aphids, thrips, mites, small larvae, and other soft-bodied insects or eggs. Adults of one species are greenish or yellowish green, with delicate lace-like wings and golden eyes. They are about 25 mm long. Larvae have elongated, spindle-shaped mandibles that distinguish them from ladybird beetle larvae. Lacewing larvae use their mouthparts to puncture bodies of prey and extract body fluids.

Lacewing eggs on silken stalks are about 12 mm above the surfaces of leaves or stems to which they are attached. The stalks may protect the eggs from natural enemies, particularly lacewing larvae. Larvae feed on aphids and other small insects.

Predaceous Bugs: Minute Pirate Bug, *Orius tristicolor* (White); Common Damsel Bug, *Nabis americoferus* (Carayon); Large Big-eyed Bug, *Geocoris bullatus* (Say)

Description and Biology: Minute pirate, common damsel, and large big-eyed bugs are representative of several species within each group that feed on sorghum insect and mite pests.

Adult minute pirate bugs or flower bugs usually are black with white markings and 2 mm long. The elongated, thickened, basal part of the front wing is yellowish white and marked by a large, triangular black spot at the tip; the membranous part of the wing is white. The insect resembles the chinch bug but is much smaller. Minute pirate bug nymphs are yellow. They feed on insect eggs, newly-hatched larvae, nymphs, small insects, and spider mites.

Damsel bugs are 8 mm long, with the body narrowed anteriorly. The front legs close tightly to grasp prey and are armed on the inner surface with a double row of short spines. Some species have both long- and short-winged forms. Most damsel bugs are

yellowish brown. Damsel bugs hide among foliage or in flowers and capture and eat aphids, caterpillars, and other insects.

Adult and nymph big-eyed bugs prey on small insects. Big-eyed bugs have large, protruding eyes. These insects are 5 mm long, with dark bodies and white wings. The front legs capture prey.

Ground Beetles: Many species, Family Carabidae

Description and Biology: Many species of ground beetles commonly are found on the ground searching for prey or hiding under stones, logs, or plant debris. Most ground beetles prey on larval or adult insects.

Adults are flattened, with long legs. Most adult ground beetles are dark in color. A few have green, blue, or copper bodies, with violet or green upper wings bordered with reddish brown. Wings of most species are marked with rows of longitudinal ridges and punctures. Adults vary considerably in size, but most range from 10 to 25 mm long.

Larvae of most ground beetles are nocturnal and predaceous with large, sickle-shaped mandibles. Fully-grown larvae are 10 to 45 mm long. Their bodies are elongated, flattened, and tapered to the tail that terminates in two bristly, hair- or spine-like processes. Larvae are dark brown or black, but some are yellow.

Ground beetles feed on soft-bodied insects and small animals found in or on the ground. Common hosts are cutworms, leaf-feeding caterpillars, grubs, maggots, naked pupae, and worms.

Insect Parasites: Braconid Wasps, family Braconidae; Ichneumonid Wasps, family Ichneumonidae; Chalcid Wasps, family Chalcidae; Tachinid Flies, family Tachonidae

A parasitic insect lives in or on one host individual that may not die until the parasite completes development. Several species of parasites suppress abundance of sorghum insect pests, especially aphids and caterpillars.

Adult braconid wasps are small (usually less than 15 mm long) and stout-bodied. Biologies of braconids are similar to those of ichneumonids except many braconids pupate in silken cocoons on the outside of the body of the host and others spin silken cocoons apart from the host. Braconid wasps parasitize many insects, but most often aphids and larvae of moths, beetles, and flies. Bodies of parasitized aphids swell and harden into "mummies". The adult wasp emerges through a circular hole it cuts in the aphid mummy's skin.

One of the most common and important braconid parasites in sorghum is *Lysiphlebus testaceipes* (Cresson). This shiny, slender black wasp commonly is seen in aphid, especially greenbug, colonies. The aphid mummies are tan to gold.

The many species of ichneumonid wasps are distributed widely. Adult size and markings vary. Most are wasp-like, and females have long ovipositors, often longer than the body. Most of these wasps are internal parasites of immature stages of the host. The parasite may complete development in the stage of the host in which the egg is laid or in a later stage. Most groups of insects are parasitized by ichneumonids.

Chalcid wasps are metallic blue or green and small (2 mm). Many species live inside minute insects or eggs of scale insects, aphids, caterpillars, or flies.

Tachinid flies resemble large house flies, are bristly, and mottled gray, brown, or black. Adults feed on flowers. They glue eggs to a host insect or on foliage where the host insect may ingest the eggs. Larvae are deposited on or in the host insect. Larvae feed on the host before pupating. Adults emerge before or just after the host dies.

Insect Pests in Foreign Countries

Insect Pests of Seed, Roots, and Seedlings

Wireworms, *Gonocephalum* spp.

White Grubs, *Holotrichia* spp.

Refer to the section on wireworms and white grubs as insect pests in the United States.

Shoot Fly, *Atherigona soccata* (Rondani)

Description and Biology: The shoot fly is widespread in almost all sorghum-growing areas of the semi-arid tropics, but is not found in the Americas or Australia. It is a key insect pest of sorghum in Asia, Africa, and Mediterranean Europe. The adult is a small, gray fly that deposits 2 mm, white, cigar-shaped eggs singly on the underside of the leaf, at the one- to seven-true-leaf stage of sorghum growth. Eggs hatch in one to three days and larvae migrate into the plant whorl. Mature larvae are yellow and about 6 mm long. The larval stage is completed in eight to ten days, and the pupal period lasts eight days. Pupation occurs in the soil. The entire life cycle is completed in seventeen to twenty-one days.

Symptoms and Damage: Larvae cut the growing point, and the central leaf of the whorl wilts and dies, resulting in the typical “deadheart” symptom. The dead leaf can be pulled from the plant and, at the base, emits an odor. The young, whitish-yellow maggot feeds on decaying plant tissue. Most damage occurs one week to one month after plant emergence. Plants attacked later produce side tillers that may be attacked. Late planting and successive planting during the rainy season increase the likelihood of attack.

Management: Effective management practices are early planting, high seeding rate, use of shoot fly-resistant sorghum varieties, and use of insecticides six to twelve days after plant emergence.

Leaf and Whorl Insect Pests

Shoot Bug, *Peregrinus maidis* (Ashmead)

Description and Biology: The shoot bug infests sorghum in India, the West Indies, and Philippines. The female is yellowish brown, and the male dark brown. Females are 1.5 times larger than males. Wings of short-winged forms extend only to the sixth abdominal segment. Long-winged forms have transparent wings. Nymphs and adults live in groups on leaves, in the whorl, and inside the leaf sheath. The female inserts one to four eggs in a slit on the upper surface of the leaf midrib and covers them with white wax. Eggs are white, cylindrical, elongate, and tapered slightly at the ends. A female lays about 100 eggs in seven days. Eggs hatch in seven to ten days. The nymphal instars are completed in about sixteen days.

Symptoms and Damage: Nymphs and adults behind the leaf sheath suck juices from whorl leaves and stems. Young plants are most susceptible. Plants weaken, redden, stunt, and may lodge. Severe infestations first kill top leaves, followed by older leaves, and occasionally the entire plant dies. High infestation at the boot stage may twist the top leaves and prevent emergence of panicles. Sooty mold grows on the honeydew excreted by the shoot bug.

Management: Several species of predators and parasites attack this insect pest. Some insecticides provide effective control.

Spittle Bug, *Poophilus costalis* Walker

Description and Biology: The spittle bug occurs in Africa and parts of Asia. From one to twenty-five nymphs rest head downward inside a foamy spittle mass on the plant. Last instar nymphs leave the spittle and are active. Adult bugs jump. They are 9 to 11 mm long and usually are brown or gray.

Symptoms and Damage: The bug usually does not cause severe damage. Feeding on sorghum leaves and within whorls causes chlorotic leaf spots and blotches. Plants may stunt and produce smaller panicles when infestation is severe. Spittle bugs become very abundant in late planted sorghum.

Management: Chemical control is not required because most infested plants do not suffer much damage but recover soon after the insects become adults and leave the plant.

Sugarcane Aphid, *Melanaphis sacchari* (Zehntner)

Description and Biology: The sugarcane aphid occurs in many areas of Africa, Asia, Australia, and tropical America. Adults and nymphs are yellow to buff colored. Abundance increases rapidly when the weather is dry or at the end of the rainy season. The wingless female produces sixty to 100 nymphs in thirteen to twenty days. The winged form produces fewer nymphs. The life cycle is completed in five to seven days during the dry season.

Symptoms and Damage: The sugarcane aphid prefers older leaves but infests younger leaves and panicles when sorghum is flowering. Nymphs and adults suck juice and stunt plant growth. Damage is more severe when the crop is moisture stressed, resulting in dried leaves and plant death. The sugarcane aphid excretes honeydew on which sooty mold grows.

Management: Many predators eat this aphid. Chemical controls usually are not required, but are effective in controlling the aphid.

Oriental Armyworm, *Mythimna separata* (Walker)

Description and Biology: The oriental armyworm is distributed throughout Asia, Australia, and the Pacific Islands, and parts of Africa. Moths have brownish front wings with dark specks and whitish- brown hind wings. Eggs are laid in batches of twenty to 100 (total 500 to 900) on the lower surface of green leaves, dry leaves, and grasses. Shiny, white, spherical eggs have ridges and hatch in two to seven days. Larval development is completed in fourteen to twenty-two days. The fully-grown larva is dirty-pale brown to dark brown with three darker brown dorsal lines. A lateral yellow stripe is on each side. The larva pupates in an earthen cell in the soil or inside the leaf sheath of the plant. The pupal period is eight to nine days.

Symptoms and Damage: Larvae feed on leaves, mostly at night, leaving only the midrib intact. Immature panicles also are damaged. Larvae migrate in gregarious bands when the food in an area is consumed. However, occurrence of oriental armyworm is sporadic.

Management: Several hymenopterous and dipterous parasites suppress abundance of oriental armyworm. Clean cultivation and low plant population suppress damage. Several insecticides are effective.

African Armyworm, *Spodoptera exempta* (Walker)

Description and Biology: This armyworm is an occasional pest of sorghum in East and West Africa. Eggs, laid in groups of about twenty on the underside of leaves, hatch in three to four days. The larval period lasts ten to twenty days depending on temperature. Solitary larvae are green; damaging gregarious larvae are black with a green underside.

Pupation is in the soil, and the adult usually emerges in one week. Adult moths migrate at night over considerable distances. Outbreaks are associated with the rainy season. In eastern Africa, infestations begin first in the south and spread northward.

Symptoms and Damage: Periodical outbreaks of African armyworms result in extensive crop loss. This insect pest also attacks pasture grasses and other cereal crops. Large infestations of gregarious larvae damage much vegetation.

Management: Outbreaks are controlled if national or international organizations apply insecticides in infested areas. Infestations must be detected early. Small infestations can be controlled by using insecticides.

Grasshoppers: *Oedaleus senegalensis* (Krauss); *Aliopus simulatrix* (Walker)

Description and Biology: These species are pests of sorghum just south of the Sahara. Other grasshopper species may be infrequent pests in other arid parts of the world. Adult *O. senegalensis* are 30 to 40 mm long and green or brown. *A. simulatrix* is 25 mm long and pale brown. Adults of both species are winged. Nymphs develop in less than two months, Both species can survive a long dry season. *O. senegalensis* survives as eggs in pods in the ground; in very dry areas, eggs may be viable for more than a year. *A. simulatrix* survives the dry season as adults, hiding in cracks in the soil. Eggs are laid during the rainy season. Both species breed continuously during wetter times of the year, and a generation is completed in forty to fifty days.

Symptoms and Damage: All stages of the plant may be attacked, but most crop loss occurs when grasshoppers attack seedlings or ripening panicles. Nymphs and adults consume sorghum, other cereals, and wild grasses. These migrant species fly at night and can increase in abundance overnight.

Management: Insecticides control grasshoppers.

Migratory Locusts: *Locusta migratoria* L.; *Schistocerca gregaria* L.

Description and Biology: Sometimes these locusts are major pests of sorghum in Africa and India. Migratory locusts solitary and swarming phases. Only when swarming are they sufficiently abundant to cause damage. Swarming adults are brown, fully winged, and about 50 mm long. Nymphs have five instars and initially are all black, becoming black and orange with age. Various shades of brown and gray also may occur in low-density populations, while solitary nymphs are green. Nymphs band together and move several hundred meters in one day. Adults swarm and migrate by day, sometimes over long distances. Each female lays approximately fifty eggs in each of three or four egg pods. Development time may be as short as three months under favorable conditions. Four generations may be produced per year. Only one or two generations are produced under less favorable conditions.

Symptoms and Damage: Nymphs and adults feed on leaves, flowers, and ripening panicles. Besides sorghum, the migratory locust attacks many varieties of grasses and occasionally other kinds of plants.

Management: Outbreaks usually start in well-defined areas, and national or international control to prevent development of outbreaks is preferable to local action. Bands of nymphs are easily destroyed by conventional insecticides.

Stalk Borers

Spotted Stem Borer, *Chilo partellus* (Swinhoe)

Description and Biology: The spotted stem borer is common in Asia and eastern and southern Africa. The moth is medium sized and straw colored. A female lays almost 500 eggs in masses of ten to eighteen near the midrib on the underside of leaves. Eggs are oval, flat, and tend to overlap like fish scales. They hatch in four to five days. The larval

period lasts nineteen to twenty-seven days. Pupation is inside the stalk. Adults emerge in seven to ten days through the larvae's entry holes. During the dry season, last-instar larvae diapause in sorghum stalks. Diapause is broken and pupation occurs, giving rise to the first generation of adults when the rainy season starts.

Symptoms and Damage: The first indication of spotted stem borer is small, elongated, transparent windows in young whorl leaves where larvae eat the upper surface but leave the lower surface intact. As larvae grow, they cause shot holes and ragged leaves when infestation is severe. Third-instar larvae move to the base of the plant and bore into the shoot, damaging the growing point and causing a typical deadheart. After panicle emergence, larvae tunnel inside the stalk. Stalk tunneling damages developing panicles that become partially or completely chaffy or breaks peduncles.

Management: Several parasites and predators suppress abundance of spotted stem borer. Plowing or otherwise destroying stubble soon after harvest is beneficial the following year. Early and uniform planting and removal of affected plants is advantageous. Several insecticides are effective. Application of granular insecticide in the whorls of infested plants provides good control.

Maize Stalk Borer, *Busseola fusca* (Fuller)

Description and Biology: The maize stalk borer is a key insect pest of sorghum in Africa. Eggs are laid in groups of thirty to150 inside leaf sheaths. A female lays 400 to 500 eggs during her five to six days of life. Eggs hatch in five to seven days. Newly-hatched larvae cluster under the leaf sheath but disperse the following night to feed on young leaves in the whorl. Larvae develop six to seven instars in twenty-four to thirty-six days, and are 35 to 45 mm when fully grown. They have buff to purple-brown bodies and a brown head. The larva cuts an exit hole for the adult before pupating in the stalk. Adults emerge in nine

to twelve days and are various colors. Usually three generations are produced per year. Third-generation larvae diapause at the onset of the dry season and develop in six to seven months.

Symptoms and Damage: Young larvae eat leaves. Mature larvae bore into stalks and produce deadhearts. With severe infestation, plant growth is retarded and flowering and grain production are reduced. Symptoms of early feeding, deadhearts, and stalk tunnelling are similar to those of damage caused by the spotted stem borer.

Management: Destruction by plowing or burning dry stalks and stubble reduces the abundance of borers. Early planting suppresses infestation. Several parasites attack the larvae and pupae.

Pink Borer, *Sesamia inferens* Walker

Description and Biology: The pink borer occurs in Asia. Moths are fawn-colored, with dark brown streaks on the forewings and white hind wings. The female lays about 400 eggs in batches of about 150 arranged in two or three rows between the leaf sheath and stalk of the plant. Eggs are creamy white and spherical, about 0.7 mm in diameter, with ridges running longitudinally from the upper pole. Before hatching in five to seven days, the color changes to brown, then gray. Fully-grown larvae are 25 mm long and pale yellow with a purple-pink tinge and reddish brown head. The larval period lasts twenty-five days but may be extended to seventy-five days during cool weather. Pupation is in the larval tunnel in the stalk, and adults emerge in twelve days. A generation may require six to seven weeks.

Symptoms and Damage: Larvae bore into the stalk and kill the central shoot, causing a deadheart. Symptoms of damage are similar to those of spotted stem borer.

Management: Management practices are the same as for the spotted stem borer.

Pink Borer (Africa), *Sesamia calamistis* Hmps.

Description and Biology: This insect is distributed widely in Africa. Moths are light beige with brown stripes. Color and markings differ by geographical area. Yellowish, spherical eggs in groups of as many as forty are laid between the leaf sheath and stalk. Eggs hatch in four to six days. After feeding on leaves, larvae bore into the stalk where they remain for two weeks. A mature larva is 30 mm long and 3.5 mm wide, with a brown head and buff body with pale-pink dorsal markings. Pupation is inside the stalk, and lasts ten days. Larvae do not diapause but survive on wild grasses or volunteer sorghum and millets.

Symptoms and Damage: Early-instar larvae feed on leaves, especially leaf sheaths. Small, elongated, transparent windows in young whorl leaves indicate where larvae have eaten the upper surface but left the lower surface intact. The plant may become ragged as severity of attack increases. Later instars bore through internodes into stalks. After panicle emergence, the stalk near the panicle is bored, causing peduncles to break, or chaffy panicles. Panicles can be attacked.

Management: Management practices are the same as for the spotted stem borer.

African Sugarcane Borer, *Eldana saccharina* (Walker)

Description and Biology: This stalk borer occurs throughout Africa south of the Sahara. The female usually lays eggs in batches of two to 200 but occasionally singly. A female lays 400 to 600 eggs in about two weeks. Eggs hatch in five to seven days. Newly-hatched larvae are 2 mm long and orange, gradually becoming dark gray. The larva is active and produces much frass. It spins a cocoon from which it emerges and feeds. Males have six to seven larval instars and females seven to eight. The larval period ranges from twenty to sixty days. Pupation occurs in a cocoon inside the stalk. The pupa

is reddish brown with a prominent dorsal ridge. The adult emerges in eight to thirteen days.

Symptoms and Damage: Newly-hatched larvae feed on leaves and bore into the midrib. Fully-grown larvae bore into stalks and cause deadhearts. Larvae hang from silken threads and sometimes are blown onto neighboring plants.

Management: Cultural management methods include destroying stubble, burying crop residues, and removing volunteer and alternate host plants. The borer has several natural enemies.

Panicle-feeding Caterpillars

Bollworm, *Heliothis armigera* (Hubner)

Description and Biology: This pest is widely distributed in Africa, Australia, New Zealand, southern Europe, and Southeast Asia. The insect is a pest of many crops. Moths are brown or gray with specks that form a "V" on each forewing. Hind wings are dull colored, with a black border. A female lays about 700 spherical, creamy-white or yellowish eggs singly on young sorghum panicles. Eggs hatch in four to six days. Young larvae are light green. Fully-grown larvae vary from almost black, brown, or green, to pale yellow or pink, with light and dark stripes. Fully-grown larvae are about 40 mm long. The larval period lasts three to four weeks. Pupation is in an earthen cell in the soil, with adults emerging in two to four weeks.

Symptoms and Damage: The larva infests the sorghum panicle and feeds on developing kernels. It also feeds on whorl leaves.

Management: Many parasites and predators, including birds, attack this insect pest. Cannibalism and bacterial and viral diseases reduce abundance. Plowing fields exposes pupae to heat and predators, thus preventing emergence of adults. Larvae on

open panicles are exposed to predaceous insects and birds. Small larvae may be controlled with insecticide.

Earhead Webworm, *Nola analis* (Wileman and West)

Description and Biology: This panicle caterpillar is a minor insect pest of sorghum in Africa and Asia. Round, creamy-white eggs are laid on spikelets and kernels. Adult moths are small and white. Behind the two prominent black spots in the middle near the anterior margin of the forewings are two zigzag, dirty-white, vertical stripes. The eggs hatch in two to three days. Young larvae are dark gray with hairs on the body. Larvae reach full size (13.5 mm) in two weeks. Larvae live inside webs formed from excrement and silken threads. Pupation is inside the webs. The conical pupa is fully covered with silken webbing. The pupal period is eight days.

Symptoms and Damage: The larva feeds on kernels of the panicle.

Management: Control is rarely necessary, but insecticides are effective.

Christmas Berry Webworm, *Cryptoblades gnidiella* (Milliere)

Description and Biology: This insect pest is increasing in importance on hybrids and high-yielding cultivars of sorghum in India. The adult has dark-gray forewings. Hind wings, fringed with hairs on the anterior margin, are larger than the forewings. Creamy-white, round or conical eggs are laid on spikelets and kernels. Eggs hatch in three to four days. The newly-hatched larva is dirty white, with a brown head. The fully-grown, dark brown, active larva is 12 mm long. The larval period is nine to ten days. Pupation occurs inside silken webs. The pupa is short and covered with silken threads secreted by the larva. The adult emerges in a week.

Symptoms and Damage: Larvae destroy kernels. They produce webs of silken thread that remain on the panicle. Heavily infested panicles may be covered with webbing.

Management: Insecticide usually is not required.

Panicle-feeding Bugs

Earhead Bug, *Calocoris angustatus* (Lethiery)

Description and Biology: The earhead bug is a very serious pest of sorghum in parts of India. This and other species of panicle-feeding bugs infest sorghum in Africa. The female is yellowish green, 5 mm long, and about 1 mm wide. It inserts long (1.5 mm), cigar-shaped eggs between the glumes or anthers of sorghum florets. Each female lays 150 to 200 eggs. Eggs usually hatch in less than a week. During a period of slightly more than two weeks, the tiny, first-instar, yellow and orange-red nymphs develop through five instars into adults. The life cycle is less than three weeks. At least two generations feed on the same crop when panicles in the field do not mature at the same time.

Symptoms and Damage: Nymphs and adults infest and suck juice from developing kernels as panicles emerge from the boot. Kernels attacked early in development are shriveled and yield less. Older kernels have feeding punctures that reduce grain quality.

Management: A reduviid bug and a lygaeid bug prey on the earhead bug. Open panicles are less affected than compact panicles.

African Head Bug, *Eurystylus oldi* Odhiambo

Description and Biology: This species is various colors. The bugs are 3 to 5 mm long, with females slightly longer than males. Colors range from pale brownish-yellow to dark brown with red markings. Cigar-shaped eggs are inserted into developing sorghum kernels, and hatch in four to six days. A female lays twenty-four to 136 eggs, and there

may be one to seven eggs in an individual kernel. There are five nymphal instars that develop in about eleven days. The life cycle is completed in eighteen to twenty-seven days.

Symptoms and Damage: This species becomes extremely abundant in sorghum with compact panicles. Nymphs and adults suck juice from developing kernels. Kernels are shriveled, small, and off-colored, resulting in yield loss. Bug-damaged kernels become infected by secondary pathogens that further deteriorate grain quality. Feeding punctures are visible on older kernels.

Management: Open panicles are less affected than compact panicles. Some sorghums are resistant to bugs. Damage is less when kernels develop during dry periods. The insect is susceptible to insecticide.

Acknowledgements

The authors are indebted to many colleagues whose contributions to the knowledge base on insect pests of sorghum were summarized in this chapter. The chapter was not written to be a literature review, but a presentation of practical aspects of sorgum insect pests and their descriptions, biologies, natures and symptoms of damage, and preventive and remedial management tactics in an IPM strategy.

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Table 1. Insect pests of sorghum in the U.S., their descriptions, damage symptoms, and management.

Insect	Description	Nature and symptoms of damage	Management
		Insect pests of seed and roots	
Wireworms (true and false), families Elateridae and Tenebrionidae	Larva of click (true) or darkling (false) beetle; shiny, slender, cylindrical, and hard-bodied, range from white or yellow, to brown.	Feed on planted seed and less on seedling plant roots. Damaged seed do not germinate, resulting in stand loss.	Encourage rapid seed germination and rotate with non-host crop. Insecticide as seed, planter box, or in-furrow treatment.
Red imported fire ant, *Solenopsis invicta* Buren	Social insect lives in colony with several castes of winged reproductives and workers reddish brown to black and 3-8 mm long; constructs mound.	Chews through thin seed coat and consumes embryo of planted seed; damaged seed does not germinate, resulting in stand loss.	Encourage rapid seed germination by planting good seed into well-prepared seed bed and firmly packing covering soil. Insecticide as seed, planter box, or in-furrow treatment.
White grubs, *Phyllophaga* spp.	Larva of May or June beetle; "C"-shaped, white body, head and legs brown; last abdominal segment transparent and digested material can be seen.	Damage results from larva feeding on roots; small seedlings often are killed, resulting in stand loss; severely pruned roots result in stunting, plant lodging, and increased susceptibility to drought and stalk rot organisms.	Rotate with nonhost crop. Base insecticide treatment on 1-2 grub/ft^2 of soil; in-furrow insecticide provides some suppression.
		Insect pests of seedlings	
Cutworms (several species), family Noctuidae	Smooth-skinned, dirty gray or brown larvae 30-50 mm long. When disturbed, curl up tightly into a “C” shape.	Feed at night and hide during day. Usually feed on seedlings and sever stems. Some feed on foliage, and some feed entirely underground on seedling roots.	Rotate with nonhost crop, and clean cultivate before planting. Insecticide applied to soil or foliage in late afternoon to prevent excessive plant or foliage loss.
Southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber	Larva is 12 mm long, creamy white and wrinkled, with a brown head. Adult is the spotted cucumber beetle.	Larva chews along roots or burrows into roots and crown, causing stand loss, stunting, deadheart, or late-season lodging.	Clean cultivate 2-3 weeks before planting. Base in-furrow insecticide application on history of problem.
Yellow sugarcane aphid, *Sipha flava* (Forbes)	Lemon-yellow aphid covered with small spines and has two double rows of dark spots down the back; very short cornicles.	Attacks soon after plant emergence. Injects toxin that causes purple-colored leaves and stunting of seedlings; yellowing of more mature leaves and delayed maturity.	Encourage rapid plant growth until 5-leaf stage. Base insecticide treatment on percent infested plants -- 10, 20, and 40 percent infested at 1-, 2-, and 3-leaf stages.
Chinch bug, *Blissus leucopterus leucopterus* (Say)	Adult is 5 mm long, black with reddish-yellow legs and white wings marked with black triangular spot at middle of outer margin; immatures resemble adults in shape but are wingless and reddish with a horizontal white band across the back.	Immatures and adults congregate and feed behind sheaths of lower leaves; suck plant juice and cause leaf reddening and wilting, and plant stunting.	Assure dense, uniform stand; promote vigorous plant growth; do not plant near small grains. Base insecticide treatment on 2 or more bugs on 20 percent of plants less than 1.25 cm high or 75 percent of plants infested.
		Insects pests of leaves and leaf whorls	
Corn leaf aphid, *Rhopalosiphum maidis* (Fitch)	Bluish-green aphid is 1.5 mm long with black legs, antennae, and cornicles; winged and wingless forms in colony.	Sucks juice, usually within the plant whorl; may cause yellow mottling of leaves; transmits maize dwarf mosaic virus.	Usually not justified. Insect may be beneficial by increasing abundance of natural enemies.
Greenbug, *Schizaphis graminum* (Rondani)	Aphid is 1.6 mm long and pale green with darker green dorsal abdominal stripe and black distal leg segments and tips of cornicles; winged and wingless forms in colony.	Sucks juice from underside of leaves, injects toxin that causes red spots, yellowing and leaf death, vectors virus, and predisposes plant to disease and lodging. Causes damage at any plant growth stage.	Resistant hybrids; base insecticide treatment on extent of plant damage at different growth stages. Biotypes exist to resistant hybrids and insecticide resistance.
Spider mites, especially Banks grass	Extremely small, to 0.4 mm; color varies from green to	Sucks juices from underside of leaves in webs; initial	Often an induced pest. Prevent plant

mite, *Oligonychus pratensis* (Banks)	yellow, with 2 darker spots on lateral margins of back; palpi and first 2 pairs of the 8 legs are salmon colored.	colonies along the midrib; leaves turn pale yellow, later red, then brown.	moisture stress. Base insecticide treatment on 33 percent of area of lower leaves infested; control is erratic.
		Insect pests of panicles	
Sorghum midge, *Stenodiplosis sorghicola* (Coquillett)	Adult is small, 2-mm-long, orange-red fly. Orange larva is cryptic within spikelet.	Adult female lays eggs in flowering spikelets; larval feeding on ovary prevents kernel development.	Early, uniform planting in region. Base first insecticide application on 1 adult per panicle at 25-30 percent flowering.
Corn earworm, *Helicoverpa zea* (Boddie)	Mature larva 38-50 mm long; varies from green, yellow, or pink to almost black, with fairly prominent longitudinal lines; dark stripe divided by narrow white line looks doubled down back.	On whorl-stage sorghum, feeds in whorl on leaves that appear ragged after emerging. Most damaging when feeds on developing kernels of panicle.	Early planting of hybrids with loose panicles. Base insecticide treatment on 2 small larvae per panicle.
Fall armyworm, *Spodoptera frugiperda* (J. E. Smith)	Mature larva 40 mm long, greenish to grayish brown, with light-colored inverted "Y"-shaped suture on head and dorsal lines running lengthwise on body.	On whorl-stage sorghum, feeds in whorl on leaves that appear ragged after emerging. Most damaging when feeds on developing kernels of panicle.	Early planting of hybrids with loose panicles. Base insecticide treatment on 2 small larvae per panicle.
Sorghum webworm, *Nola sorghiella* Riley	Mature larva 12 mm long; reddish to yellowish brown, flattened and marked with four longitudinal reddish to black stripes; densely covered with hair.	Larva feeds on and chews circular holes in developing kernels of panicle.	Early planting of hybrids with loose panicles. Base insecticide treatment on 5 small larvae per panicle.
Rice stink bug, *Oebalus pugnax* (Fabricius)	Straw-colored, shield-shaped bug 12 mm long.	Sucks juices from developing kernels causing them to be smaller, softer, and lighter weight than nondamaged kernels; commonly, fungi infect damaged kernels causing them to be black.	Usually less abundant on early-planted sorghum. Base insecticide treatment on 5 bugs per panicle.
Southern green stink bug, *Nezara viridula* (L.)	Green bug 19 mm long; typically shield-shaped.	Sucks juices from developing kernels causing them to be smaller, softer, and lighter weight than nondamaged kernels; commonly, fungi infect damaged kernels causing them to be black.	Usually less abundant on early-planted sorghum. Base insecticide treatment on 4 bugs per panicle.
Conchuela, *Chlorochroa ligata* (Say)	Varies from dull olive or ash gray to green, purplish, pink, or red brown; has orange-red band along lateral margins of thorax and margins of wings and a spot of the same color on the back at base of wings.	Sucks juices from developing kernels causing them to be smaller, softer, and lighter weight then nondamaged kernels; commonly, fungi infect damaged kernels causing them to be black.	Usually less abundant on early-planted sorghum. Base insecticide treatment on 4 bugs per panicle.
Leaffooted bug, *Leptoglossus phyllopus* (L.)	Brown, oblong, with white band extending across forewings; 20 mm long; tibiae of hind legs dilated or leaf-like.	Sucks juices from developing kernels causing them to be smaller, softer, and lighter weight then nondamaged kernels; commonly, fungi infect damaged kernels causing them to be black.	ETL is six bugs per panicle. Usually less abundant on early-planted sorghum.
False chinch bug, *Nysius raphanus* Howard	Bugs 9 mm long, mottled gray.	Sucks juices from developing kernels causing them to be smaller, softer, and lighter weight then nondamaged kernels; commonly, fungi infect damaged kernels causing them to be black.	Usually clumped on panicles and in areas in a field. Usually less abundant on early-planted sorghum. Base insecticide treatment on 140 bugs per panicle.
		Insect pests of stalks	
Sugarcane borer, *Diatraea saccharalis* (Fabricius); neotropical borer, *D. lineolatus* (Walker); southwestern corn borer, *D. grandiosella* Dyar; Mexican rice borer, *Eoreuma loftini* (Dyar)	Mature larva 25 mm long; creamy white and marked with brown to black spots.	Larva bores into stalk; may cause reduced stalk diameter, deadheart, or lodging.	Early planting; stubble destruction; good cultural management; insecticide usually not required.

Table 2. Estimated yield loss based on symptoms of yellow sugarcane aphid damage to one to three true-leaf sorghum plants.

Symptom	Percent loss per plar
No discoloration	0
Localized discoloration	8
Less than one entire leaf discolored	11
One entire leaf discolored	31
More than one leaf discolored	54
More than two leaves discolored	77
Dying or dead plant	100

Table 3. Economic injury levels based on the percentage of sorghum seedlings infested by yellow sugarcane aphid.

Control cost ($) per	Crop market value ($) per hectare										
	250	300	350	400	450	500	550	600	650	700	750
	Percentage of seedlings infested at the one true-leaf stage										
15	15	12	11	10	9	8	7	6	6	5	5
20	20	16	14	12	11	10	9	8	8	7	7
25	25	20	17	15	13	12	11	10	10	9	9
30	30	25	21	18	16	14	13	12	11	11	10
	Percentage of seedlings infested at the two true-leaf stage										
15	26	21	18	16	14	13	12	11	11	10	10
20	35	28	23	20	18	17	16	15	14	13	13
25	44	35	29	25	23	21	19	18	17	16	16
30	52	43	36	31	28	25	23	21	20	19	18
	Percentage of seedlings infested at the three true-leaf stage										
15	67	53	46	41	36	33	31	29	27	25	24
20	89	72	61	54	49	44	40	37	35	33	32
25	*	90	76	67	61	55	50	46	43	40	38
30	*	*	91	81	73	66	60	55	51	47	44

* Do not treat

Table 4. Economic threshold levels for greenbug on sorghum at different plant growth stages.

Plant size	When to treat
Emergence to 5 cm	Twenty percent of plants visibly damaged (plants beginning to yellow), with greenbugs on plants.
Larger plant to boot	Greenbug colonies causing red spotting or yellowing of leaves and before any entire leaves on twenty percent of plants are killed.
Boot to heading	At the death of one functional leaf on twenty percent of plants.
Heading to hard dough	When greenbug numbers are sufficient to cause death of two normal-sized leaves on twenty percent of plants.

Table 5. Economic injury levels based on the number of adult sorghum midge per flowering panicle of sorghum.

Control cost ($) per	Crop market value ($) per hectare										
	250	300	350	400	450	500	550	600	650	700	750
	Number per panicle of susceptible sorghum										
15	2.4	2.0	1.8	1.5	1.3	1.2	1.1	1.0	0.9	0.9	0.8
20	3.0	2.6	2.3	2.0	1.8	1.6	1.5	1.3	1.2	1.1	1.0
25	3.7	3.4	2.9	2.6	2.3	2.0	1.8	1.6	1.5	1.3	1.2
30	4.5	4.1	3.6	3.2	2.8	2.5	2.2	1.9	1.7	1.5	1.4
	Number per panicle of resistant sorghum										
15	12.0	10.0	9.0	7.5	6.5	6.0	5.5	5.0	4.5	4.5	4.0
20	15.0	13.0	11.5	10.0	9.0	8.0	7.5	6.5	6.0	5.5	5.0
25	18.5	17.0	14.5	13.0	11.5	10.0	9.0	8.0	7.5	6.5	6.0
30	22.5	20.5	18.0	16.0	14.0	12.5	11.0	9.5	8.5	7.5	7.0

Table 6. Economic injury levels based on the number of corn earworm and fall armyworm larvae per sorghum panicle.

Control cost ($) per	Crop market value ($) per hectare										
	250	300	350	400	450	500	550	600	650	700	750
15	1.5	1.3	1.1	0.9	0.8	0.8	0.7	0.6	0.6	0.5	0.5

20	2.0	1.7	1.4	1.2	1.1	1.0	0.9	0.8	0.7	0.6	0.6
25	2.5	2.1	1.8	1.6	1.4	1.2	1.1	1.0	0.8	0.7	0.7
30	3.0	2.6	2.3	2.0	1.7	1.5	1.3	1.2	1.0	0.9	0.8

Table 7. Economic injury levels based on the per-panicle number of adult rice stink bugs infesting sorghum at the milk or soft-dough stages of kernel development.

Control cost ($) per	Crop market value ($) per hectare										
	250	300	350	400	450	500	550	600	650	700	750
	Infestation beginning at the milk stage of kernel development										
15	7	6	6	6	5	5	5	4	4	4	3
20	8	7	7	6	6	6	5	5	5	4	4
25	8	8	7	7	6	6	6	5	5	5	4
30	9	8	8	7	7	6	6	6	5	5	5
	Infestation beginning at the soft-dough stage of kernel development										
15	9	8	8	7	7	6	6	6	5	5	5
20	10	9	9	8	8	7	7	6	6	6	5
25	12	11	10	10	9	9	8	8	7	7	6
30	13	12	11	10	10	9	9	8	8	7	7

Table 8. Economic injury levels based on the per-panicle number of adult southern green stink bugs conchuelas and leaffooted bugs infesting sorghum at the milk or soft-dough stages of kernel development.

Control cost ($) per	Crop market value ($) per hectare										
	250	300	350	400	450	500	550	600	650	700	750
	Infestation beginning at the milk stage of kernel development										
15	5	4	4	4	4	3	3	3	3	2	2
20	5	5	5	4	4	4	4	3	3	3	3
25	6	6	5	5	5	4	4	4	4	3	3
30	7	6	6	6	5	5	5	4	4	4	4
	Infestation beginning at the soft-dough stage of kernel development										
15	8	7	7	6	6	5	5	4	4	3	3
20	9	8	8	7	7	6	6	5	5	4	4
25	10	9	9	8	8	7	7	6	6	5	5

30	11	10	9	9	8	8	7	7	6	6	5