Management of Arthropod Pests in Conservation-Tillage Systems in the Southeastern U.S.

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For centuries crops have been produced using a system that mechanically manipulates the soil a number of times for the purpose of improving soil structure, managing crop residues and/or controlling weeds. In the U.S. this has usually involved plowing and one or more diskings followed by one or more cultivations after crop emergence. This system is commonly referred to as conventional-tillage.

With the development of selective, efficacious herbicides and planting equipment that will function in minimally disturbed soil, various conservation-tillage systems have evolved. Conservation-tillage has been defined by the National Conservation Tillage Information Center in Ft. Wayne, IN, as any tillage and planting system that retains at least 30 percent residue cover on the soil surface after planting. Such systems include reduced-till, mulch-till, strip-till, ridge-till and no-till (slot) planting.

Although various pest problems have been encountered, producers continue to adopt various conservation-tillage systems because these systems significantly reduce soil and water erosion, conserve soil moisture and fossil fuel, reduce soil compaction, save time and labor, require lower investment in equipment and optimize the use of land resources. Over the past decade, the potential pest problems in the more diverse conservation-tillage environments has concerned entomologists. Current entomological research has shown that broad generalizations about pest problems associated with conservation-tillage systems are not appropriate. Each crop and pest situation must be evaluated and independent judgments made.

In my discussion pest problems associated with conservation-tillage systems throughout the U.S. will be presented, but emphasis will be placed on specific pest problems associated with conservation-tillage systems in the southeastern U.S. These pests will be categorized as seed/seedling and post seedling.

SEED/SEEDLING PESTS. Conservation-tillage practices generally minimize the losses from soil insects. Gregory and Musick (1976), however, reported that some pests have become more serious on crops because herbicides eliminated preferred host(s).

Soil insects are among the most difficult insects to control. Insecticides have limited efficacy as they are difficult to properly time or place at the site of the infestation. In addition, early identification of damaging populations of soil insects is difficult, and limited information on action thresholds is available.

Failure of seeds to germinate or emerge is not always a result of feeding by a specific pest(s). In cool, wet springs seeds may rot in the soil as a result of poor seed-soil contact and/or cooler soil temperatures associated with heavy mulch covers. Before definitive statements on stand reductions are possible, the seed must be examined for evidence of attack by a pest(s).

The following discussion addresses some of the seed/seedling pests of major concern in crops grown using conservation-tillage practices in the southeastern U.S. No attempt will be made to identify specific pesticides, as new and more effective chemicals are continually being developed. Current pesticide recommendations can be obtained from publications of your Cooperative Extension Service.

Southern Corn Billbug, *Sphenophorus callosus* (Oliver). As a major pest of corn. the southern corn-billbuq causes siqnificantlv qreater losses in no-tillage than conventional-tillage systems-(All et ai. 1983). Adult southern corn billbugs feed in the pith/meristem of corn and produce symptoms varying from mild foliage perforations to severe stunting and death of seedlings (Metcalf 1917). Stage of plant growth when feeding occurs and the length of time billbugs have access to a feeding site are important in determining the degree of damage that will occur (Durant 1982). However, factors that promote vigorous seedling growth increase tolerance to billbug feeding. Fast-growing seedlings can "outgrow" moderate billbug damage. Larval survival is low on later plant-growth stages (Wright et al. 1983).

Southern corn billbug adults are active at the time of corn planting, and highest populations in conventional-tillage systems are associated with unplowed weedy areas near fields (Metcalf 1917). In continuous no-tillage systems, spring populations of billbugs in corn are associated with weeds and corn debris from the previous season. In double-cropping systems with corn following a small grain, the spring generation of billbugs occurs in the small grain and infests corn after it is planted (All et al. 1983; All, unpublished data).

Various management techniques suppress billbugs in conservation-tillage systems. Cornfields with a history of southern corn billbug problems should not be planted using no-tillage practices unless billbug populations have been reduced by other control measures, such as insecticides. The southern corn billbug does not attack legumes; thus crop rotations with these crops should be considered. The use of subsoiling in fields with hardpan layers aids plant recovery from billbug feeding, especially under drought conditions. When billbug infestations are high, insecticide applications used in conjunction with subsoiling in no-tillage systems act synergistically to improve corn growth and yield and reduce damage (All and Jellum 1977, All et al. 1983).

Corn Root Aphid, Anuraphis maidiradicis (Forbes), and the Cornfield Ant, Lasius allenus (Forster). The corn root aphid and attendant ants are one of the most interesting pest complexes in nature. Gregory (1974) considered the corn root aphid to be the most important pest of no-tillage corn in Kentucky.

The honeydew secreted by the corn root aphid during feeding is collected by the ants. The aphid feeds on a variety of grasses, but it appears to prefer corn. The ants often move aphids considerable distances in the spring to establish them on corn. Young corn plants, may wither and die, especially under drought conditions. Gregory (1974) reported stand losses exceeding 50% in some fields, although conventional-tillage corn also has been severely infested. Most infestations in conservation-tillage were associated with corn planted in grass sods or with areas that have not been planted in field crops for several years. It is unclear if the no-tillage habitat per se favors outbreaks.

Growers in regions with historically serious corn root aphid problems should be cautious when using no-tillage systems for the first time, especially when fields have laid fallow for one or more years. In these situations, a thorough examination of the field for ant mounds is recommended. Because early-spring deep-tillage operations disrupt and destroy the ant nests in fields with high ant populations, conventional-tillage in ant- and aphid-infested regions should be considered for one or two years before initiating a no-tillage program, Selection of a nonhost crop, such as soybeans, also may be advisable for high-risk areas. Highly effective insecticides are available.

Sugarcane Beetle, Euetheola rugiceps (LeConte). Severe infestations in corn by The suqarcane beetle have been observed in conservation-tillaqe systems (J. N. All, unpublished data). Although the biology of the sugarcane beetle is not well known, infestations in conventional-tillage systems are usually associated with crops grown in freshly tilled sod fields or fields high in organic matter. Affected seedlings wither and die as if drought-stricken. Examination of dying plants reveals large gouge-like wounds in the pith tissue, usually at or slightly below the soil surface. Heavy beetle infestations have been observed in crops using both no-tillage or conventional-tillage systems. In general, heaviest damage is located adjacent to wooded areas and/or pastures. In double-crop systems utilizing conservation-tillage methods, small grains may serve as larval hosts from which adults emerge and attack corn.

At present, the hazard of the sugarcane beetle as a major pest in conservation-tillage systems is not clearly established. However, caution should be exercised when any crop is planted following a pasture or in other sods where high larval populations have been observed. Deep plowing is recommended for recurring sugarcane beetle infestations. Little information is available on the efficacy of insecticides against this pest.

Lesser Cornstalk Borer, Elasmopalpus lignosellus (Zeller). This insect is a significant pest of many major field crops in the southern United States. Losses to lesser cornstalk borer are high in conventional-tillage and certain conservation-tillage systems (i.e., especially those using various disking systems). No-tillage cropping systems are considered an effective management strategy for this pest (All and Gallaher 1976; All 1978, 1979a; All et al. 1982).

The lesser cornstalk borer has a semisubterranean biology. Larvae attack many crops including corn, sorghum, or soybeans. Devastating infestations have occurred in these field crops especially if droughty weather occurs for several weeks after planting. In similar environmental situations, damage is often greatly reduced if the second field crop is planted using the no-tillage system (All 1978). Lesser cornstalk borers are polyphagous, and larvae are often present in small grains or weeds when fields are plowed (All and Gallaher 1977; All et al. 1979). The disking operations either bury or chopup plant residues, leaving them exposed for rapid desiccation. These tillage operations have little, if any, impact on the resident lesser cornstalk borer populations; therefore, larvae are present in the field and attack the second crop as soon as it germinates.

The lesser cornstalk borer is a semisaprophagous insect that is capable of completing its development on plant residues in no-tillage systems (Cheshire and All 1979a, b). Although resident populations are present in no-tillage situations, they seem to be, in effect, deterred from feeding on the germinating field crop because of the abundant food source in the surrounding environment (All 1980b). Use of no-tillage practices, whenever feasible, in double-cropping systems using corn, sorghum or soybeans following harvest of small grains would avoid damaging populations of the lesser cornstalk borer. If conventional-tillage or more intensive conservation-tillage operations are followed, planting should be delayed for at least two weeks to allow resident populations of the lesser cornstalk borer to complete development and leave the area or to succumb to starvation. Because soybeans have consistently lower infestations of this pest (Rogers and All 1982), they should be given high priority in double-cropping systems when damage from lesser cornstalk borer is likely.

Insecticides may be used to control lesser cornstalk borer infestations (All et al. 1979; All 1979b; Gardner and All 1982). However, acceptable control is difficult to achieve, especially under dry soil conditions (Tippins 1982).

Other Seed/Seedling Pests. In areas other than the southeastern U.S. a variety of other pests occur in crops grown using conservation-tillage systems. The armyworm (Pseudalatia unipuncta (Haworth)) is a serious problem in conservation-tillage systems for corn production in the north-central U.S., especially when a rye cover crop precedes corn planting (Musick and Petty 1973, Wrenn 1975). Maggots (Musick and Beasley 1978), stalk borer (Musick and Beasley 1978, Stinner et al. 1984), corn rootworms (Kirk et al. 1968, Musick and Collins 1971, Chaing et al. 1971, Gregory and Musick 1976), slugs (Musick and Petty 1973) and rodents (Beasley and McKibben 1976) also have been problems in conservation-tillage systems of corn production. The black cutworm (Agrotis ipsilon (Hufnagel)) on corn (Musick and Beasley 1978) and cotton (Dumas 1983) and the variegated cutworm on cotton (Gaylor unpublished data) have posed sporadic problems. Wireworms (Gregory 1974, Edwards 1975, Musick and Beasley 1978) also have caused occasional sporadic problems on several crops in the north-central and northwestern **U.S.** White grubs (Musick and Petty 1973, Gregory 1974, Rivers et al. 1977) have damaged several crops in many regions of the U.S. Birds (J. N. All, unpublished data) have been pests on several crops using conservation-tillage systems of crop production.

POSTSEEDLING PESTS. Several pests attack crops following seedling establishment and infest the plant throughout the vegetative, fruiting and maturation stages. In general, the hazard from infestations by pests in this group is similar in all tillage systems. Information currently available indicates that the survey methods, action thresholds and control procedures developed for these pests in conventional-tillage systems are readily adaptable to conservation-tillage systems, but field studies are required to verify the extent of the problem for each pest/crop situation.

Corn Earworm, *Heliothis* zea (Boddie). The corn earworm is a major pest of corn and other field crops (soybeans, small grains, etc.) when conservation-tillage production systems are followed.

Increases in injury from the corn earworm in corn have not been observed in conservation-tillage systems, except when crops are planted later than normal (All and Gallaher 1976). Roach (1981a) reported that *Heliothis* spp. populations were similar in comparisons of conservation-tillage and conventional-tillage systems in cotton and tobacco. However, he found that greater numbers of moths emerged from the conservation-tillage plots (Roach 1981b). Serious damage from the corn earworm has occurred on corn and sorghum planted as the second crop in a double-cropping system (All 1980a).

Concern has been expressed that several insects, like the corn earworm, will be favored in conservation-tillaqe systems because pupation sites are not destroyed by tillage and because ground cover provides protection from natural enemies (Hoards 1970, Watson et al. 1974, Roach 1981b). This has not occurred probably because higher populations of natural enemies occur in conservation-tillage. The level of predation of pupating earworms appears to be higher in conservation-tillage. Also, *Heliothis* spp. pests feed on a wide variety of crop plants and have a strong migratory behavior. Dispersal patterns from conservation-tillage fields appear to be similar to that from conventional-tillage fields.

Crop selection is a wise pest-management consideration for corn earworm control in certain conservation-tillage systems such as double-cropping, where late planting dates often cannot be avoided. Soybean as the second crop would receive substantially less damage from late-season earworm populations than would corn or sorghum as the second crop (All and Rogers 1983). A wide variety of effective insecticides are available for control of earworm infestations (All 1979c). The use of insecticides particularly in corn is not always economical due to an unfavorable cost/benefit relationship as a result of low crop value and/or the necessity for multiple applications.

Grasshoppers, Redlegged Grasshopper, Melanoplus femurrubrum (DeGeer); Differential Grasshopper, Melanoplus differentialis (Thomas); Migratory Grasshopper, Melanoplus sanguinipes (Fabricius), etc. Recent studies indicate that grasshoppers may be a significant problem in certain conservation-tillage systems (Sloderbeck and Edwards 1979, D. A. Crossley, Inst. of Ecology, University of Georgia, Athens, personal communication, Aug. 1983). Grasshoppers are the paradigm of grazing insects. Crop decimations by these pests are well known throughout the world. Grasshopper infestations in conservation-tillage systems have been reported for double-cropping systems where corn, sorghum or soybeans follow small grains in a rotation. Although no major outbreaks of grasshoppers in large-scale conservation-tillage operations have been reported, the potential should be recognized in order to avoid the devastations from grasshoppers.

In double-cropping systems, close examination of fields during the germination and seedling phase of the second crop following small grains should be made, especially in areas with periodic grasshopper outbreaks. Action thresholds vary with crops, grasshopper species and region. Information developed for conventional-tillage crops in a particular region should be applicable to conservation-tillage systems. Occasional intensive-tillage operations may be required in some regions to reduce the numbers of overwintering eggs. Grasshopper populations tend to build up in weedy habitats and migrate into crops; thus good early-season weed control in the areas adjacent to crop fields and in small grains may be beneficial. Resistant varieties of sorghum should be selected over nonresistant corn or soybeans if this rotation is compatible with the farm-production program. Grasshoppers can be controlled with a variety of insecticides.

Sorghum Midge, Contarinia sorghicola (Coquillett). The sorghum midge is a major pest of sorghum in many areas of the world. In direct comparisons midge damage in conservation-tillage systems is usually similar (J. N. All, unpublished data) to that observed in conventional-tillage systems. In conservation-tillage sorghum midge outbreaks have been observed in double-cropping situations where sorghum was planted late. Also, heavy infestations have occurred in no-tillage systems where johnsongrass, control is poor and moderate to high johnsongrass levels were present during the sorghum fruiting period. Johnsongrass is attacked by the sorghum midge and has been implicated as an early-season host of overwintering populations. In many areas, the flowering of johnsongrass coincides with peak midge emergence in the spring and is an important factor in promoting the development of damaging midge infestations in sorghum (Roth and Pitre 1975).

Control of johnsongrass and early planting of sorghum have proved to be effective in conventional-tillage systems and should be utilized in conservation-tillage sorghum where possible. Because early planting may not be feasible in certain conservation-tillage systems (i.e., double-cropping), the selection of short-season and uniform-flowering sorghum varieties should be helpful.

Sorghum midge adults are vulnerable to several insecticides. An insecticide program for midge control may be necessary in areas with a history of midge outbreaks. Spray applications of insecticides must be made during the period of sorghum flowering when adult midges are active (Huddleston et al. 1972).

Fall Armyworm, Spodoptera frugiperda (J. E. Smith). Damage from the fall armyworm is similar to that from the corn earworm in many respects. The fall armyworm has a strong migratory habit, and in many areas-of the United States damage increases greatly as the growing season progresses. Devastating infestations have occurred in both corn and sorghum. But, like the corn earworm, high population levels are influenced more by late planting than by the tillage system.

Moths lay batches of eggs on foliage, and during outbreaks larvae quickly devour seedlings, leaving only a stub. If infestations occur when corn is silking, up to six larvae can be found in an ear, often reducing the ear to pulp (Sparks 1979). In the South, the fall armyworm is considered a limiting factor to the efficient production of corn in double-cropping systems. Direct comparisons of no-tillage and conventional-ti1lage systems associated with double-cropping practices indicate that infestations were initiated sooner on young corn seedlings in the conventional-tillage system (All 1980b). Little damage was observed in no-tillage systems while the seedlings were growing within the small-grain stubble. However, as the seedlings grew and became exposed above the mulch, infestations occurred rapidly and damage to older corn seedlings was equal to that observed in the conventional-tillage system.

If feasible, late plantings should be avoided to reduce fall armyworm damage. In double-cropping conservation-ti1lage systems where fall armyworm hazards are high, crop selection is important. Soybeans and other legumes are less preferred by fall armyworm than grass crops. Of the grasses, sorghum is less vulnerable than corn. Because damaging infestations occur rapidly, early detection of fall armyworm populations is especially important. A reliable, yet inexpensive, method of determining the onset of fall armyworm infestations is placement of red surveyor's flags in susceptible crops. Moths readily oviposit on these flags, and infestations can be detected before serious feeding damage commences (Thomson and All 1982). Insecticides that are effective in conventional-tillage systems are equally efficacious in conservation-tillage systems (All 1980a).

Virus Diseases. The two major virus diseases, maize chlorotic dwarf and maize dwarf mosaic, can be serious problems in conservation-tillage systems (All 1983) of corn production. The epidemiology of these diseases involves the interaction of the vectors, the pathogens, and the overwintering weed host of the pathogens, johnsongrass. This represents a unique multifaceted challenge for pest management (All et al. 1981, All 1983).

Maize chlorotic dwarf and maize dwarf mosaic both profoundly affect corn growth. The most striking symptom of both diseases is stunting of plants, often resulting in severe yield reductions. Maize chlorotic dwarf virus is transmitted by leafhoppers, particularly the black-faced leafhopper, Graminella nigrifrons Forbes. Maize dwarf mosaic virus is vectored by several species of aphids. Both diseases overwinter in rhizomes of johnsongrass, which is the only perennial host of these viruses.

The presence or abundance of the vectors and presence of the overwintering host of the pathogens, johnsongrass, at various times in the season influence the rate at which disease is spread within fields. An additional and highly important aspect of the impact of these diseases is the time when the infection occurs in corn. In general the younger the plant at inoculation, the greater the severity of the disease(s) and the loss in yield.

A variety of management strategies for maize chlorotic dwarf and maize dwarf mosaic may be considered. The objective is to disrupt one or more links in the virus/vector/johnsongrass/corn interaction. Corn hybrids with moderate to high tolerance for the diseases are available. Some systemic insecticides, applied at planting, effectively control the leafhopper vectors of maize chlorotic dwarf and result in reduced disease loss (All et al. 1976, 1977; All and Alverson 1979). These systemic insecticides, although effective against aphids, are not effective in reducing transmission of maize dwarf mosaic (Kuhn et al. 1975). Early planting of corn results in reduced disease incidence because large vector populations are avoided. Also, irrigation and optimum fertilization practices are useful in aiding tolerance of corn to the diseases. The threshold for reducing johnsongrass populations to minimize the incidence of the virus diseases is lower than the threshold to eliminate **it** as a weed pest. Therefore, crop rotation with a noncereal crop, like soybeans, may be advisable in situations where a history of the virus disease and johnsongrass coexist. This tactic has special merit since over-the-top herbicides can be used throughout the season in soybean fields to eradicate johnsongrass, and disease-free corn production may be possible during subsequent years (All 1983).

The optimum management strategy for maize chlorotic dwarf and maize dwarf mosaic in conservation-tillage systems is a program utilizing all of the tactics outlined. However, cost/benefit relationships indicate that disease-resistant hybrids and early planting are the most efficient management strategies for these diseases. At-planting applications of systemic insecticides in combination with these tactics may be justified when disease levels are high or when the pesticide also is used for other pests that are present (All 1983).

Miscellaneous Postseedling Pests. Several other insect pests attack postseedling stages of crops and are potentially damaging in conservation-tillage plantings. Limited research data are available on the relative impact of some of these pests in conservation-tillage systems, but their biologies in conventional-tillage systems suggest that the impact of these pests may be important. The southwestern corn borer, *Diatraea grandiosella* (Dyar), and the southern cornstalk borer, *Diatraea crambidoides* (Grote), have been observed at low levels in continuous no-tillage cornfields (Gregory and Musick 1976; All and Gallaher 1976). Various defoliating pests such as the soybean looper, *Pseudoplusia includens* (Walker), the green cloverworm, *Plathypena scabra* (Fabricius), the velvetbean caterpillar, *Anticarsia gemmatalis* Huebner, and several species of armyworm occur on conservation-tillage crops at about the same intensity as in conventional-tillage. Mexican bean beetle, *Epilachna varivestis* Mulsant, populations were reduced in soybeans planted in no-tillage systems compared directly to conventional-tillage (Sloderbeck and Edwards 1979). The chinch bug, *Blissus leucopterus leucopterus* (Say), has been observed intermittently in double-croppingsystems of no-tillage corn planted after harvest of small grains for silage or grain.

Bird problems occur in harvest-stage crops. Damage to corn is common, and bird losses in sorghum can be tremendous in conservation-tillage systems. However, observation indicates that bird problems in harvest-stage crops are similar in conventional-tillage and conservation-tillage systems (J. N. All, unpublished data).

BIOLOGICAL CONTROL. The environment near the soil surface in conservation-tillage systems provides a habitat that supports higher numbers and a greater diversity of arthropods than does conventional-tillage systems. Many of these arthropods, particularly spiders and Carabidae and Staphylinidae beetles, are predatory on many pest insects (House and All 1981; Blumberg and Crossley 1982; McPherson et al. 1982; House and Stinner 1983). When high populations of predators are present in conservation-tillage fields at the time crops are germinating and becoming established, reduction in damage by seed/seedling pests has been substantial. The actual role of predatory arthropods in controlling pests in conservation-tillage systems needs further study. The process involves a complex interaction between many abiotic and biotic factors in the unique environment of a particular conservation-tillage system. It is becoming increasingly evident that these predatory arthropods aid in preventing outbreaks of pests in crops produced using conservation-tillage systems.

Increased moisture, reduced temperature and reduced lighting occur within the mulch residues and on the soil surfaces under conservation-tillage systems. Such conditions are more favorable for the development of certain disease epizootics in pest populations (Burges and Hussey 1971). Several insect pathogens, especially fungi and entomophilic nematodes and perhaps viruses and bacteria, may be enhanced in conservation-tillage habitats. Higher populations of entomophilic rhabditoid nematodes were observed in no-tillage as compared to conventional-tillage sorghum (M. C. Saunders and J. N. All, unpublished data). Additional research is needed on the influence of conservation-tillage systems on insect pathogens.

CONCLUSIONS. Insect pest management in conservation-tillage systems is complex. Current knowledge indicates that some pests may behave differently in conservation-tillage systems than in conventional-tillage systems. However, management strategies still involve long-standing principles of applied entomology. The entomologist's challenge has been and still is to develop management programs based on the biological idiosyncrasies of the insect/crop/environment interaction. When anxiety and ignorance about the impact of conservation-tillage on pest problems are eliminated, management strategies can be developed. In conservation-tillage systems it is apparent that many of the pest-management strategies that have been developed for specific pests in conventional-tillage systems are readily adaptable to conservation-tillage systems. In certain situations, such as with cutworms, wireworms, aphid-ant complexes, slugs, rodents and birds, new pest-management strategies must be developed. Generally, agronomic practices that promote rapid growth and establishment of the crop for specific site conditions (i.e., soil type, fertility, hybrids) are important. The depredation of pests is minimized when optimal growing conditions occur.

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