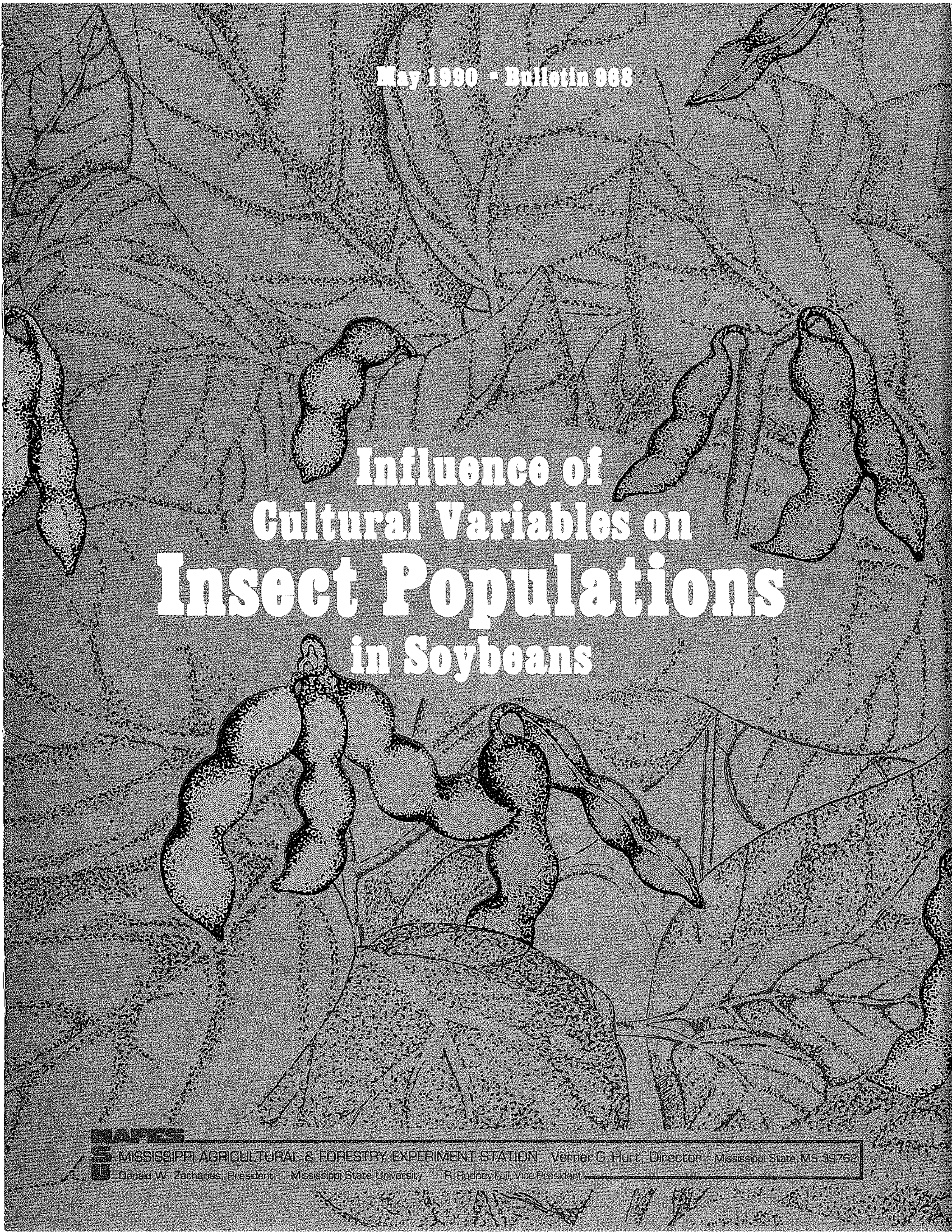

May 1990 - Bulletin 968

Influence of Cultural Variables on Insect Populations in Soybeans

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Published by the Department of Information Services, Division of Agriculture, Forestry, and Veterinary Medicine, Mississippi State University. Edited by Keith H. Remy, Publications Coordinator. Cover designed by Betty Mac Wilson, Artist.

Influence of Cultural Variables on Insect Populations in Soybeans

H. N. Pitre and R. P. Porter

Abstract

Cultural variables in agricultural production influence soybean insect populations and associated crop damage. Thus, the oldest of crop protection methods – cultural operations – should be considered in developing integrated insect pest management programs. These cultural operations impact on the biological and ecological relationships between insects and crop and noncrop vegetation. Particular emphasis in recent years has been given to more modern approaches to pest management utilizing cultural variables in crop production systems. These include date-of-planting, variety selection, row spacing, tillage, trap crops, doublecropping, and irrigation. The influences of these cultural variables can be observed by examining the impact of soil type and soil management, vegetational diversity, and insecticide interactions on pests and beneficial arthropods in various soybean cropping systems.

Introduction

Soybeans, *Glycine max* (L.) Merr., are grown alone or associated with cotton, corn, rice, peanuts, and/or grain sorghum in North America (Figure 1) and most of the Western Hemisphere. As soybean acreage increased in the Americas, so did the pest problems encountered with the extensive cultivation of this legume, believed to be native to eastern Asia (Hymowitz, 1970). There are at least 10 species of insects that may annually cause economic damage to soybeans in North America, but soybeans are usually a secondary host.

Some economic pests of soybeans in the Americas migrate from Central and South America into the continental United States. Species that commonly colonize other crops and/or noncrop vegetation build up on these hosts during early season and may damage soybeans during mid- to late-season. These pests move to soybeans when the primary host plants become unacceptable. The extent of these infestations and damage to the soybean crop are based on the number of insects moving from the primary host(s), the stage of development of the soybean crop when infested, and the duration of the infestation period.

The insect pests that coevolved with soybeans in the Orient, which are capable of fully exploiting soybeans as a food source, have not been introduced into the Western Hemisphere. Thus, the insect pests encountered on soybeans in the Americas have adapted to this crop. Because of the relatively short temporal association of these insects with soybeans, the pests

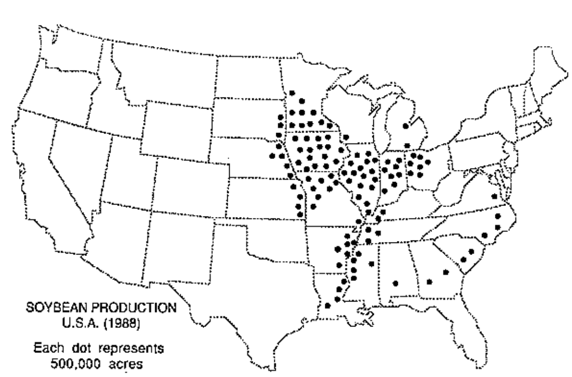

Figure 1. Major soybean producing areas in the United States. Map indicates 1988 production; each dot represents 500,000 acres.

and their natural enemies (beneficial arthropods) lack stability in their relationship with the soybean crop.

A wide range of insect pests attack and cause economic injury (Figure 2) and yield loss to soybeans in most areas with tropical and lower mid-latitude climate. The list of economic insect pests presented by Lambert (1988) includes species that feed on the roots, stems, stalks, foliage, and fruit. In some soybean-producing areas, crop damage is below economic levels because of several factors, including low populations of pest species, ability of the plants to compensate for insect damage, inadequacy of soybeans as host for the pest(s),and/or the crop escapes damage because the plant phenology is not synchronized with damaging levels of the pest population. When insect and plant phenological relationships are in synchrony, the pests may cause serious injury to the plants, resulting in economic crop yield loss.

Modifications to the crop production system may reduce colonization of the crop by insect pests and alleviate crop damage and losses caused by insect pest infestations. Injury to the plants may be avoided by producing the crop at times when pest populations are at low levels and/or in stages of development that do not damage the crop (Herzog and Funderburk, 1986). Modifications of crop production practices may alter the microclimate of the within-plant crop habitat, thus reducing establishment and injury levels of damaging pest insects. Alterations in cropping practices can have dramatic influences on pest biology and behavior. When these biological parameters are clearly defined, the relationships of insect pests with the soybean crop can be elucidated for use in developing and refining cultural control practices for specific insect pests or complexes of pests in soybeans.

Although chemical control methods are routinely employed to protect crops from insect pests, other approaches to insect pest control are available. Probably the oldest of these is cultural control. Cultural controls are the deliberate alterations of a production system (cultural practices) to reduce pest populations or avoid crop injury (Ashdown, 1977). Herzog and Funderburk (1985) described cultural controls as modifications of habitats that can create or destroy ecological niches for either pest or beneficial species. Thus, a single factor, or combination of factors can be used to regulate insect pests. Cultural control methods can be used to (1) impede insect colonization of a crop, (2) create adverse conditions that reduce the survival of the pest(s), and (3) modify the crop so damage by an infestation is minimal.

This bulletin considers some crop production practices that can influence infestations of insect pest and beneficial species in soybeans. Some attention is given to the direct and/or indirect influence of these cultural practices on biological parameters of particular insects. The apparent biological relationships responsible for the observed effects will be discussed, if known.

Crop Variety

The degree to which soybean production practices can be modified for insect control purposes is often dependent upon the crop variety selected for planting in specific agronomic situations. Therefore, variety selection is considered here to be a key to modifications that can be made in cultural practices.

Soybean types (varieties) selected for planting are usually chosen on the basis of yield and maturity date. When the crop is planted late or doublecropped behind another crop, late-maturing soybeans are selected for planting. Thus, earliness of plant maturity may not be a crop practice that can be utilized by some farmers for insect pest control. Soybeans that are planted late are often exposed to large late-season infestations of insect pests. A soybean type with short maturity is exposed less to most of the economic pests for a given geographic location than late-maturing soybeans (Litsinger and Moody, 1976).

Farmers may have the opportunity to select crop varieties with insect resistance characteristics, but unfortunately, soybean cultivars with resistance are not readily available for commercial use. Lambert (1988) considers this insect control approach in his review on host plant resistance to *Heliothis* spp. He mentions research indicating that some soybean accessions from maturity Groups VII and VIII of the World Collection showed high levels of resistance to foliage feeding by the corn earworm, *Heliothis zea* (Boddie); tobacco budworm, *H. virescens* (F.); soybean looper, *Pseudoplusia includens* (Walker); velvetbean caterpillar, *Anticarsia gemmatalis* (Hubner); and beet armyworm, *Spodoptera exigua* (Hubner). The choice of soybean variety can influence the development rate and relative fitness of a pest species (Beach and Todd, 1987). These effects may be attributed to larval antixenosis (nonpreference) or antibiosis (harmful effect on the insect resulting from larval feeding on the host plant). Oviposition may be reduced because of feeding on certain soybean varieties (Beach et al., 1985). The soybean variety influences the ability of the insect to damage the crop, time spent in a life cycle and ultimately the number of pest generations completed during the growing season.

Planting Date

Planting date may be dictated to some degree by weather, soil moisture, time constraints on the farmer, variety selection, and crop production system.

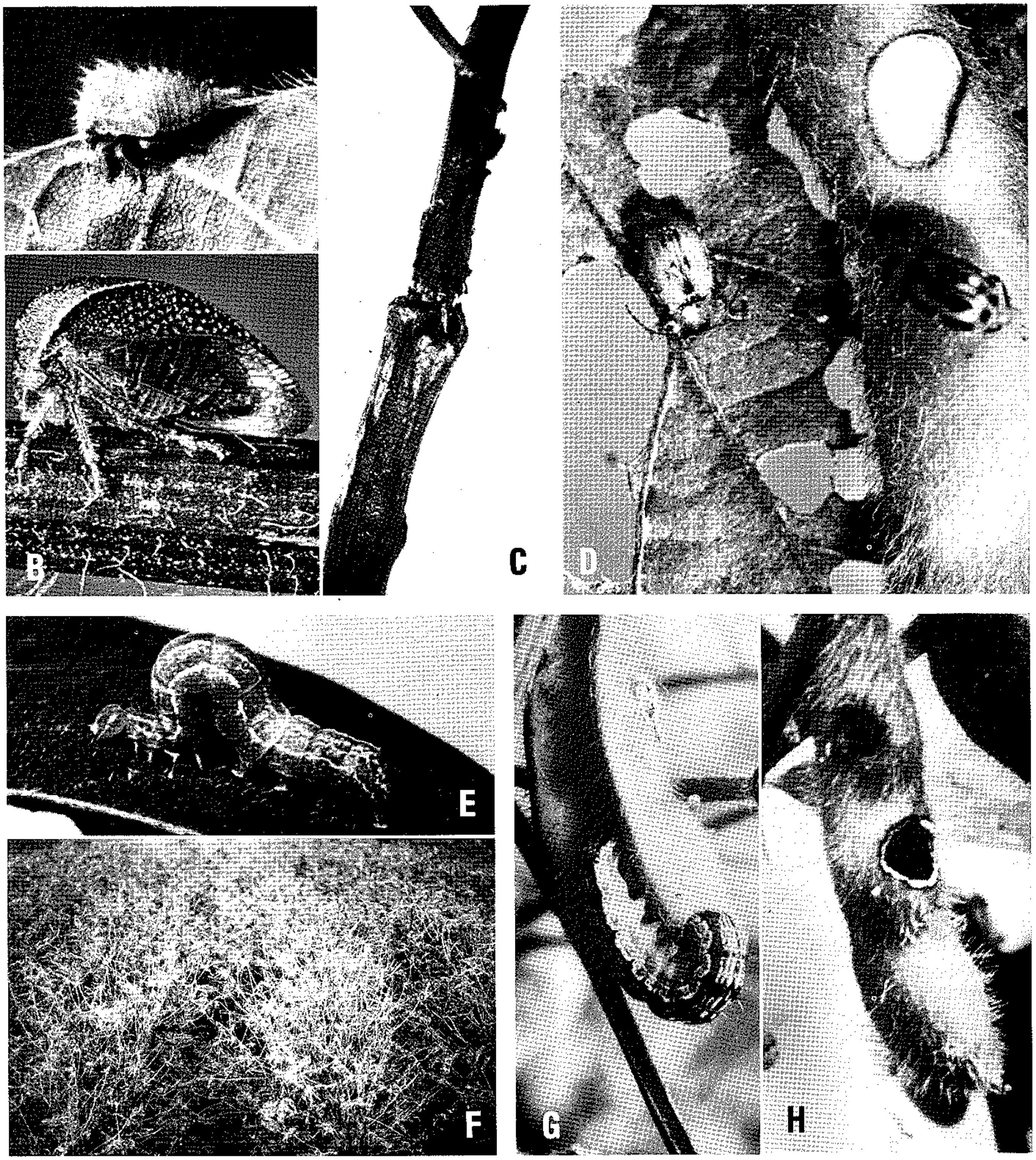

Figure 2. (A) Threecornered alfalfa hopper (TCAH) nymph; (B) TCAH Adult; (C) stalk girdled by TCAH. (D) Bean leaf beetle adults, two color types, and leaf and pod damage. (E) Soybean looper; (F) leaf feeding damage by soybean looper. (G) Corn earworm; (H) pod damage by corn earworm.

When soybeans are the main crop, planting of several varieties of different maturity dates is desirable to optimize harvest operation over time. The farmer must know which varieties produce highest yield on his farm and how they respond to insect attack. Early maturing soybean varieties may not have high yields and may not fit well into early planting schemes in many areas in the United States (Herzog and Funderburk, 1985), but this planting practice is becoming more popular with availability of new, high-yielding Group III and IV soybean types (Anonymous, 1989).

Defoliating caterpillars tend to be most abundant in late-planted, late maturing soybeans (Sloderbeck and Edwards, 1979; Boethel, 1984; Buschman et al., 1981). Preferred times for oviposition by pest insects on soybeans can be related to crop phenology and crop growth characteristics (Sloderbeck and Edwards, 1979; Boethel, 1984; Hillhouse and Pitre, 1976). For example, a soybean crop with open canopy (Figure 3a)

Figure 3. Above: soybeans with open canopy (plants not overlapping row middles). Below: soybeans with closed canopy (plants overlapping row middles).

in full bloom is more attractive and may experience heavy *Heliothis* infestations as compared to a crop with closed canopy (Figure 3b) and past the bloom stage. Crop phenology may also affect the relative fitness of insect pests in their ability to establish infestations on the plants (Terry et al., 1987). As plants mature past the pod-elongation stage, they may be less attractive to some lepidopterous defoliators, whereas stink bug infestations generally occur during this period. Predators don't appear to respond this strongly to crop maturity (Buschman et al., 1984).

Plant Density (Row Width)

Row width in soybean production is less critical than with most crops because of the ability of plants to compensate for altered plant densities. When plants are water-stressed, plant density should not be high (not greater than 8 plants per foot of row on 40-inch rows), since high-density plantings use more water (Ferguson, 1988). With increased interest in soil conservation, and because the soybean crop may be planted late in soils with low moisture, there is a trend for narrow-row soybean production in some areas. This practice is often associated with no-till or reduced tillage cultivation, which will be discussed later in this bulletin. Soybeans in narrow rows (7-30 inches) with closed canopy are preferred by some insect species for oviposition and/or larval establishment (Mayse, 1978; Sprenkel et al., 1979; Buschman et al., 1981; Boethel, 1984; Troxclair and Boethel, 1984). Insect predators often show positive responses to the increased number of prey in the soybean crop, although they may not be influenced directly by row spacing or plant density (Dietz et al., 1976; Sprenkel et al., 1979).

Wide-row soybean plantings are easily sampled with a ground cloth (Figure 4a) or sweep net (Figure 4b), but narrow-row soybean plantings are difficult to sample. Because of the narrow rows, it is virtually impossible to use the conventional ground cloth procedure in sampling for arthropods. This is especially true for narrow-row soybeans planted with a grain drill. Therefore, the conventional sweep net has been the method of choice when sampling soybeans in narrow rows. The relative numbers obtained with a sweep net, although useful to crop consultants and researchers, need to be properly calibrated against reliable absolute sampling techniques for conversion to estimates of actual insect population density. Information is available for converting sweep net counts to absolute counts in wide- and narrow-row soybeans (Pitre et al.).

Insecticide efficacy is reduced in narrow-row soybean plantings compared to wide-row plantings, but the magnitude of the reduction is dependent upon the

Figure 4. Soybeans above are being sampled using a ground cloth while those below are being sampled using a sweep net (photo below is from slide provided by D. Boethel).

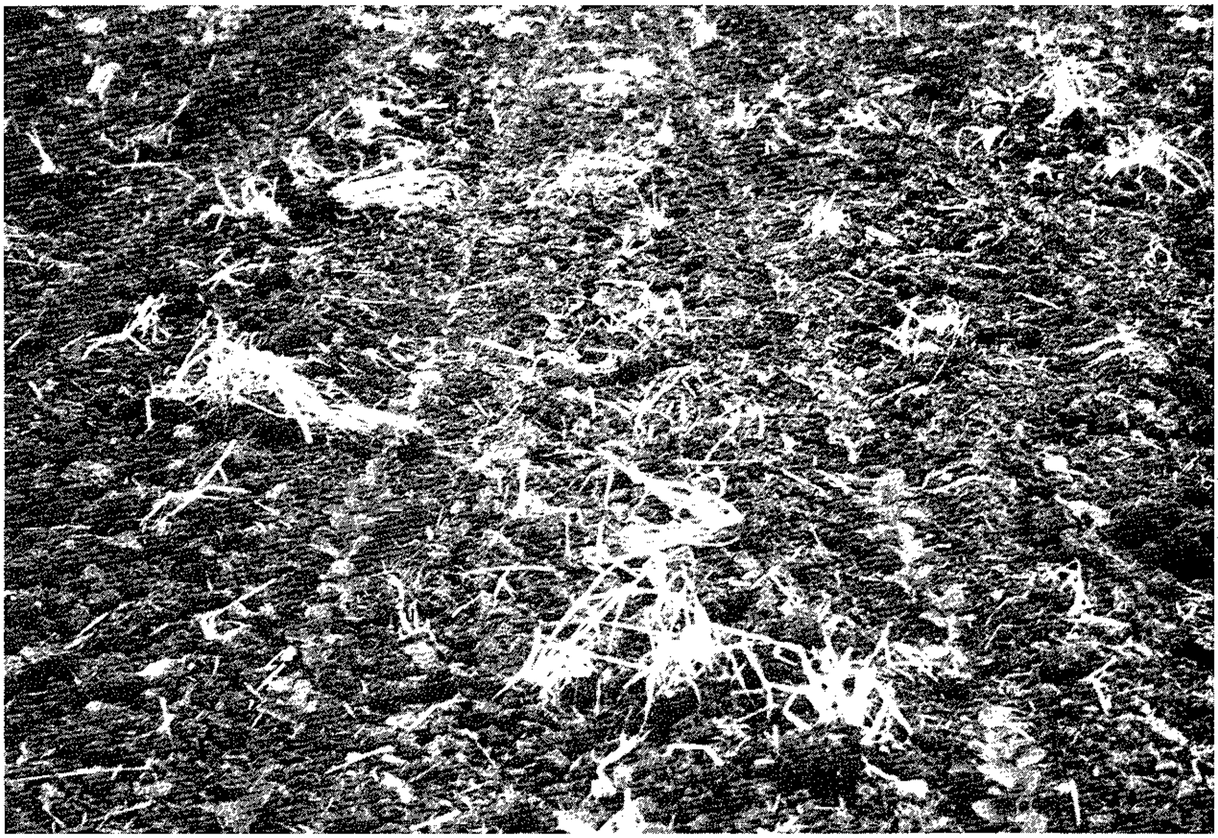

Figure 5. The soybeans above were planted using reduced tillage. The photo below shows soybeans, which were planted with no-tillage, after the harvest of wheat.

pest species and its behavior on the plant (Hutchins and Pitre 1984, 1987a, 1987b). The dense foliage in narrow-row soybean plantings hinders insecticide spray penetration into the canopy more than wide-row plantings, resulting in lower levels of insect pest control in the narrow-row plantings. Application efficiency may be increased when the insecticide is applied by ground rather than aerial equipment, particularly against hard-to-kill insect pests (Hutchins and Pitre, 1985).

Tillage

The most primitive insect control practices are mechanical, but to be of maximum benefit these practices need to be timed to susceptible stages in the life cycle of the insect pest(s) (Gebhardt, 1979). Tillage consists of operations to turn soil, bury residue, prepare the seedbed, and cultivate the crop. Most soybean pests and their natural enemies are affected by tillage to some extent (Herzog and Funderburk, 1985). Reduced or no-tillage (Figure 5) production practices reduce production costs and are being used in some areas where there is need for soil conservation, preservation of soil moisture, or where soybeans are planted late, often behind another crop. Soil planted to no-till may be cooler than similar conventionally-tilled soils, thus influencing aspects of pest biology and behavior. Noncrop vegetation in minimum tillage and no-tillage systems plays an important role in the dynamics of insect pest and natural enemy populations. Weeds and organic matter in or on the soil serve as protection, oviposition sites, and sources of food for insects (Hammond and Funderburk, 1985). These systems commonly support a higher species diversity and density of insects than conventionally-tilled systems.

Soil Insect Pests

No-till systems supported higher numbers of seed corn maggots, *Delia platura* (Meigen) (Hammond and Stinner, 1987a), and gray garden slugs, *Agriolimax reticulatus* (Muller) (Hammond, 1985; Hammond and Stinner, 1987b) than conventional tillage, whereas the soybean nodule fly, *Rivellia quadrifasciata* (Macquart), was not affected by tillage (Koethe et al., 1986).

Foliage Insect Pests

Plowing is suspected to increase mineralization and nitrogen availability (Stinner, 1981), thus the nitrogen content in plants in conventionally-tilled systems may be higher than in plants in reduced tillage systems. Plants in conventional tillage might be expected to experience greater herbivory than plants in no-till, since nitrogen appears to influence grazing rates in insects (Mattson, 1980).

Potato leafhoppers, *Empoasca fabae* (Harris) (Hammond and Stinner, 1987b), and green cloverworm, *Plathypena scabra* (Fabricius) (Sloderbeck and Yeargan, 1983), were not as abundant in no-till as in conventional tillage; whereas, grasshoppers (Figure 6) were more abundant in no-tillage fields. Funderburk et al. (1989) reported that pre-plant tillage had no gross effect on the population dynamics of the velvetbean caterpillar, green cloverworm, or southern green stink bug, *Nezara viridula* (Linnaeus) (Figure 6). Funderburk et al. (1989) indicated that reduced tillage is an acceptable way to optimize the presence of beneficial species in the field and increase the level of biological control.

Beneficial Insects

Predators, e.g. ground beetles (Figure 7) (House and Stinner, 1983), play an important role in the partial regulation of both grazing and detrital feeding insects. They are particularly influenced by soil tillage operations, whereas predators and parasites (Figure 8) on the foliage are affected little by these operations and play an important role in regulating foliar pests.

Non-Crop Vegetation

Tillage and previous cropping history influence the weediness of crop fields. These weeds modify the diversity and abundance of insect species infesting the crop. Foliage feeders, like velvetbean caterpillar, green cloverworm, and Mexican bean beetle, *Epilachna varivestis* (Mulsant), can be found in higher numbers in weed-free fields than in weedy fields (Altieri et al., 1981; Shelton and Edwards, 1983). High predator populations in weedy fields are responsible for reduced pest numbers in these fields. Although the advantages of weedy fields are apparent for control of certain insect pests, this management technique will not be easily accepted among agricultural scientists or producers (Herzog and Funderburk, 1985).

Crop System Diversity

Interest in alternative cropping practices is increasing. New crop production techniques may be discovered principally through novel disruption of the agroecosystem (Litsinger and Moody, 1976). Modifications of the cropping system by cropping system diversification might include rotation, planting a trap crop or crops, interplanting, doublecropping, strip cropping, and other variations in planting.

Rotation

Rotating crops usually has its greatest success against pests with long generation cycles and limited dispersal capabilities, e.g. the whitefringed beetle,

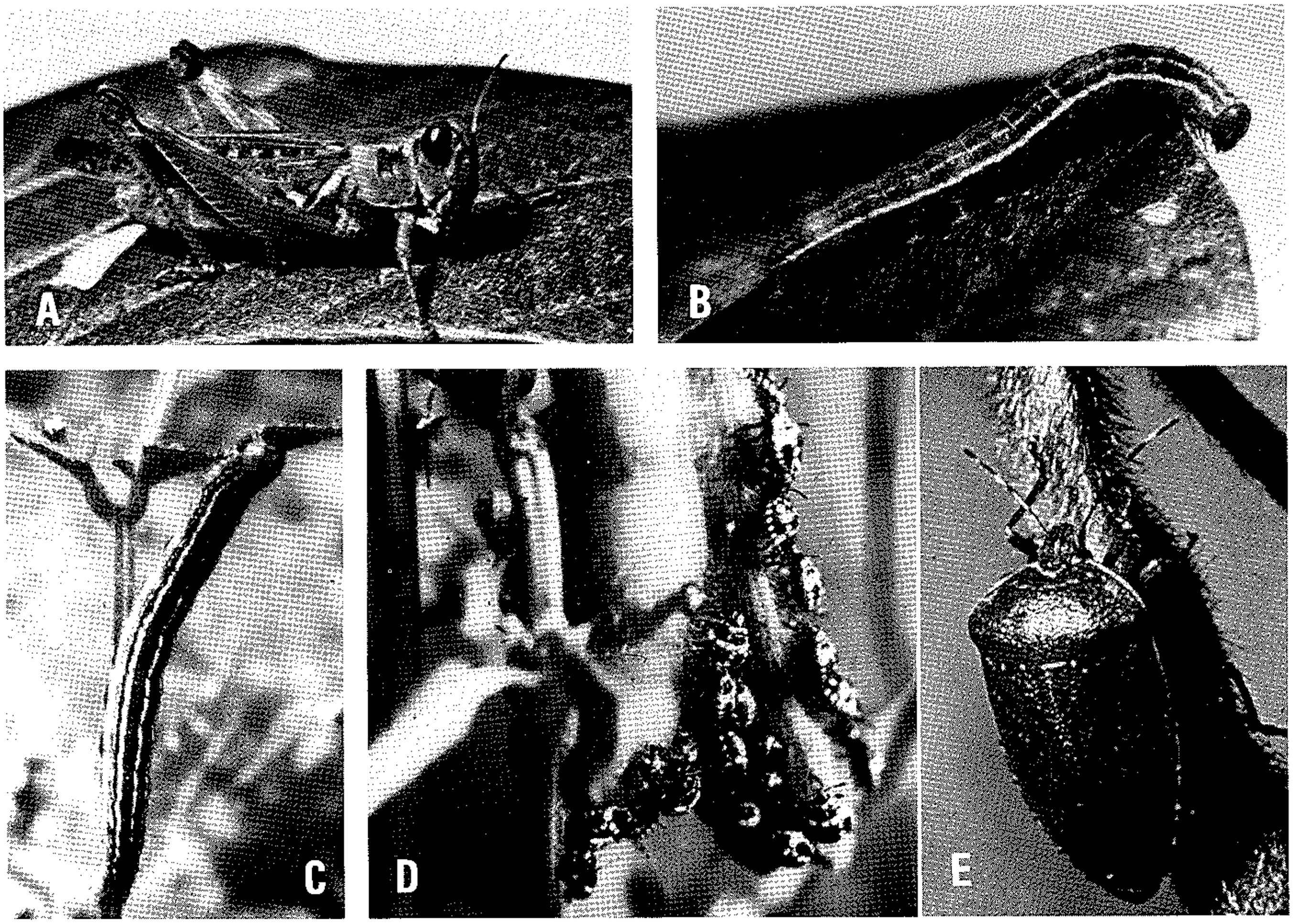

Figure 6. (A) Red-legged grasshopper; (B) green cloverworm; (C) velvetbean caterpillar; (D) southern green stinkbug nymphs and (E) adult.

Graphognathus sp. (Herzog and Funderburk, 1985). Whereas adjacent vegetation may be the key to establishing pest infestations on soybeans, e.g., soybean looper feeding on cotton nectar to enable heavy egg laying on soybeans (Burleigh, 1972; Jensen et al., 1974), crops (soybean or other crops) planted early (trap crop) and adjacent to the main planting can be important in reducing populations of pest species on the main soybean crop.

Trap Crop

The use of trap crop methods has proved beneficial against the bean leaf beetle (Newsom and Herzog, 1977) and stink bugs (McPherson and Newsom, 1984). Growers in an area must cooperate on planting date(s) in using trap crop methods for insect control. The trap crop is planted earlier (approximately 10% of planted acreage) and matures earlier than the main crop, thus attracting the insect pest(s) to the early-planted area where they may be controlled, if desired. However, the trap crop could serve as a nursery for pest insects if attention is not given to planting dates, pest buildup on the trap crop, and timing of control measures on the trap crop (if needed). The advantages of trap cropping include (1) economy, in that the area sprayed with insecticide is reduced; (2) minimum impact on beneficial insects; (3) minimum environmental pollution; and (4) delays development of insecticide resistance in the insects (McPherson and Newsom, 1984).

Interplanting

One disadvantage of monocultural practices is that pest species tend to build to economic levels because they have greater potential to expand under the conditions of reduced competition or interference. The literature shows that intercropping reduces pest infestations (Litsinger and Moody, 1976). The lower numbers of specific insects in interplanting systems may be attributable to chemicals released by nonhost plants of the pest, which adversely impact herbivorous pest species (Litsinger and Moody, 1976).

They also suggest that nonhost plants may chemically "mask" the presence of host species from potential attack. Additionally, plant mixtures in the field create more ecological niches for carnivore, as well as herbivore, populations.

Intercropping and stripcropping (crops planted in strips) may be responsible for increased beneficial insect populations and decreased pest populations, but as cultural practices for control of insect pests on soybeans, they have not gained as much attention by researchers as on other crops, e.g. corn-bean systems (Altieri, 1980). Herzog and Funderburk (1986) point out that intercropping strategies may be most practical when the main crop is an intensely-managed, high-value crop, and the interplanted crop is capable of withstanding large populations of pests with relatively minor economic loss. This may be an acceptable practice in the future, but today, intercropping is used most often in subsistence agricultural systems, generally in areas where soybeans are not produced in large commercial operations.

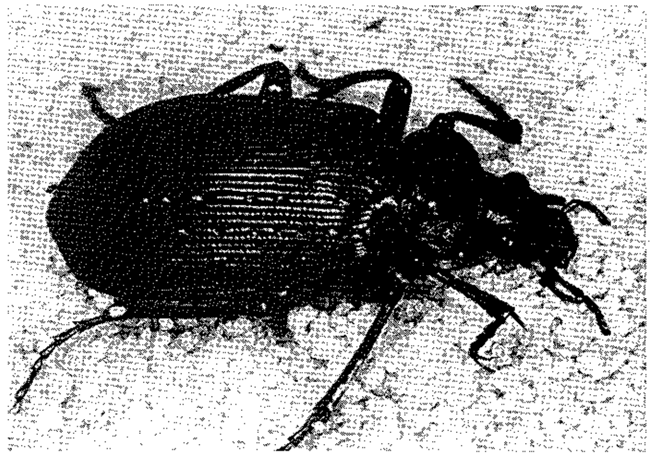

Figure 7. Ground beetle adult.

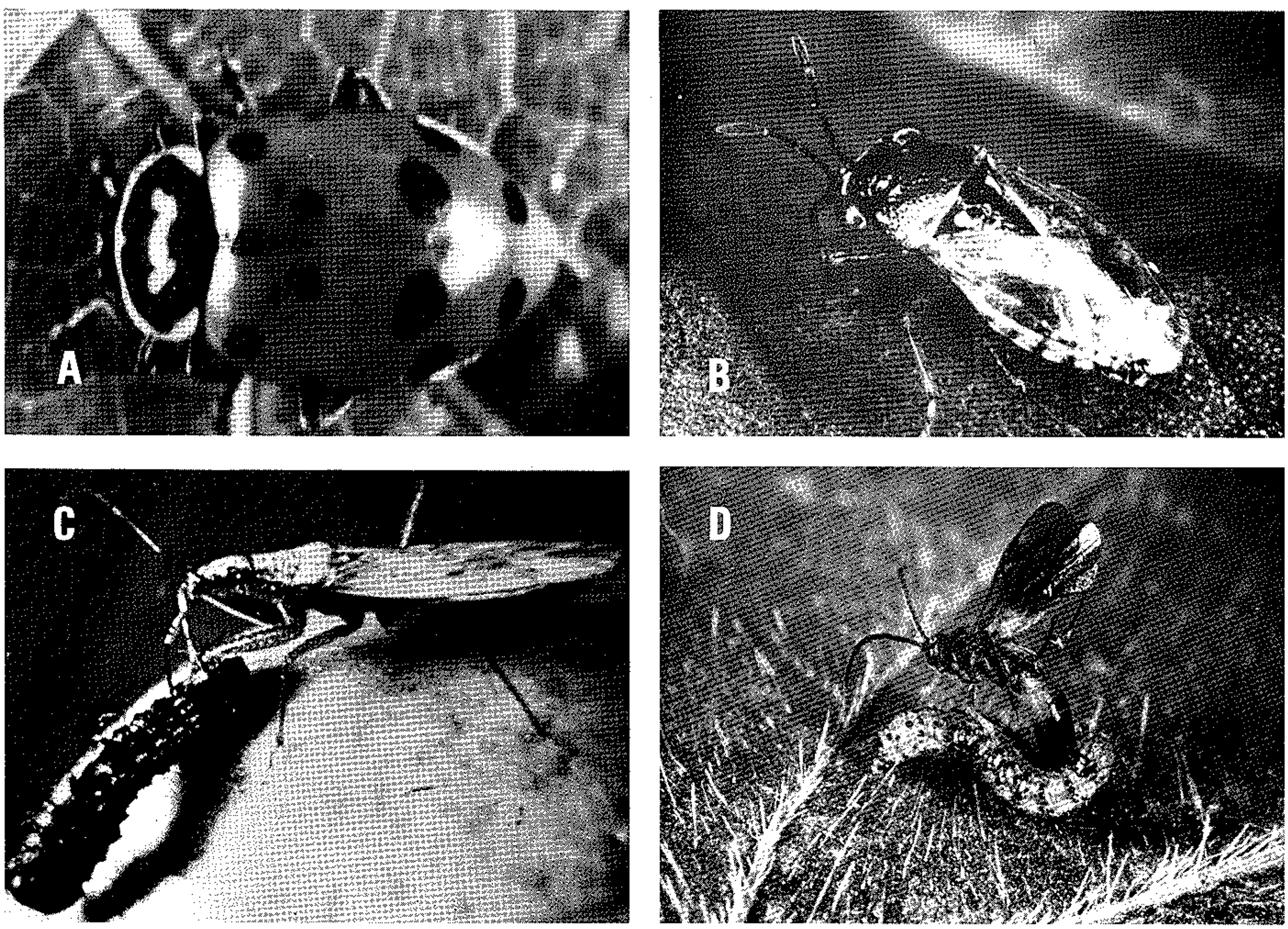

Figure 8. (A) Lady beetle; (B) big-eyed bug; (C) damsel bug; and (D) parasitic wasp.

Doublecropping

Doublecropping is an agricultural practice where two crops are produced on the same land during a 12-month period. This system of planting soybeans has received considerable interest by farmers in some areas during the past decade, particularly because of their critical cash flow situation. In the southern United States, for example, most doublecropped soybean acreage is planted immediately after spring harvest of wheat. Growing doublecropped soybeans increases producer risk of poor yield because of late planting dates, lack of soil moisture, weed problems, late-season insect problems, and the possibility of cold damage or inability to harvest the crop because of such late-season problems as the inability to drive equipment over wet soil. Management of many insect pest species that attack soybeans may be intensified by the cultural practices associated with effective doublecrop farming (Pedigo et al., 1981; Hammond and Jeffers, 1983). The influence of these cultural practices, including tillage, planting date, and row spacing in doublecropping systems on insect populations in soybeans was reviewed by Pitre (1985).

Irrigation

Irrigated soybeans (Figure 9) may have increased nutritional value and altered foliage canopy microclimate as compared with nonirrigated soybeans. These factors can contribute to insect pest infestations on soybeans. Early-season moisture stress reduces the number of branches and trifoliolates on the plants, thus providing an open leaf canopy, while irrigation assures a closed canopy. The closed canopy shades the lower leaves, lowers the canopy temperature, and maintains a higher relative humidity, resulting in a situation comparable to narrow-row soybeans.

In general, closed canopy soybeans have greater potential for damage by defoliating Lepidoptera, but also harbor higher numbers of beneficial insects (Micinski and Rabb, 1982; Boethel, 1984; Pitre, 1985).

Insect pests react differently to irrigation. Most pest and beneficial arthropods, with the exception of beet armyworms, soybean podworms, and bigeyed bugs, were more numerous in irrigated, closed-canopy soybeans than in nonirrigated, open-canopy soybeans (Felland, 1989). In some situations, the cooler and more humid microenvironment of closed-canopy soybeans allows early colonization by beneficial insects (Felland, 1989) and increased insect pathogen dispersal and infectivity (Thorvilson et al., 1985), which contribute to biological control of insect pests.

Summary

Methods of cultural control of insect pests are accomplished with modifications of crop production practices which may include tillage, planting date(s), row spacing, irrigation, and diversification of cropping systems. Selection of soybean varieties for planting using specific crop production practices under specific agronomic conditions is critical to modifications that may be made in crop management for insect pest control. Although variety selection is often based on yield and maturity date, farmers should plant soybean varieties with resistance to pests, when they are commercially available.

Implementation of successful cultural control practices utilizes information on insect seasonal occurrence, pest infestation levels required to cause economic crop losses, associations of pest and beneficial species with crop and noncrop vegetation, host plant resistance relationships, impact of host plants on insect population dynamics, and synchrony of occurrence of damaging stages of pests with critical plant growth stages. Insect pest and beneficial arthropod species react differently to densities of crop plants and noncrop vegetation, but in general narrow-row soybean plantings provide a favorable environment for pest and beneficial species usually encountered in soybeans. Irrigation, like narrow-row plantings, contributes to the early development of a closed canopy, which provides an attractive habitat for many insect species.

Insect populations often increase in early and mid-season to economic infestation levels in mid- to late-season, thus late-planted soybeans may be exposed to damage during critical stages of development (reproductive stages). Beneficial arthropods may be unable to regulate the explosive pest populations. Several insects damage soybeans during early plant development stages. Therefore, efforts should be made to plant the crop so that it escapes these early season infestations.

Tillage practices influence both the crop and arthropod pests in soybean fields. Noncrop vegetation competes with crop plants for space and soil nutrients, but provides diversity for establishment of a more stable agroecosystem. Insects are more damaging in weed-free fields than in weedy fields. This same effect can be observed in diversified cropping systems, including stripcropping, intercropping, and doublecropping, where the main soybean crop is damaged less than soybeans in monoculture.

Trap cropping practices are effective against some pests that are highly attractive to specific stages of the soybean plant at specific times during the growing season. Rotation of the crop away from the previous year's production site can be beneficial in

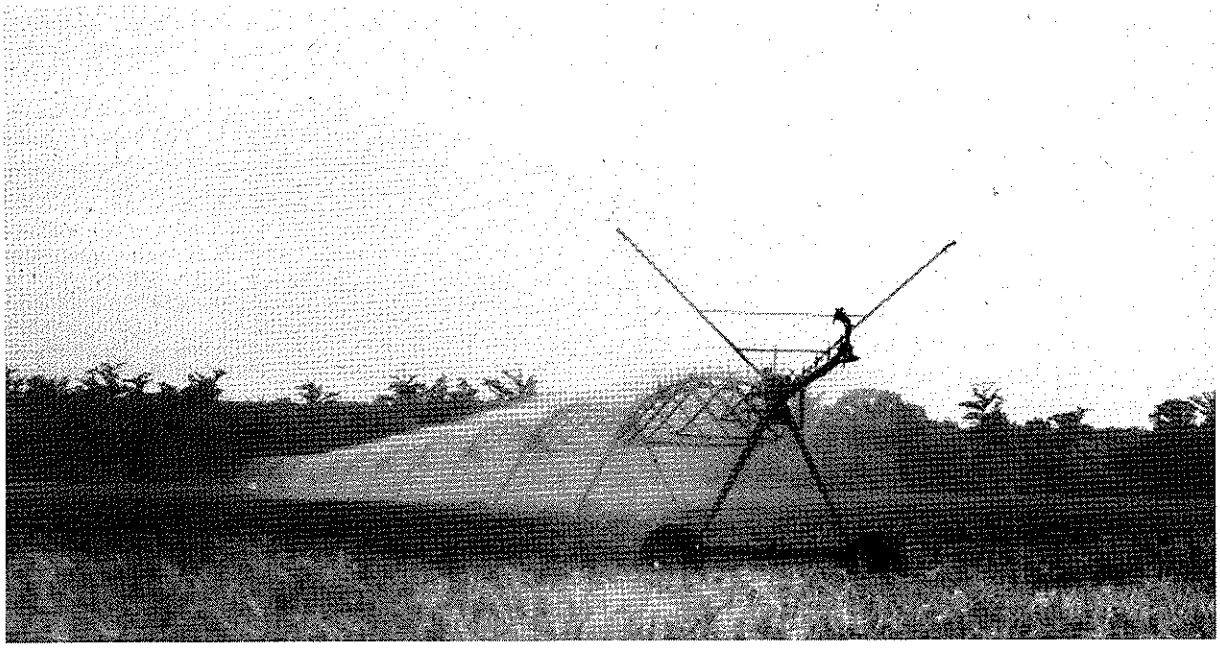

Figure 9. Soybeans above are being irrigated with pivot irrigation; those below are being irrigated with furrow irrigation.

reducing infestations of some pests.

Soybean cropping practices must consider the complex of pests, including insects, diseases, and weeds, attacking the crop at specific phenological stages, and times of occurrence of the pest(s) in developing a successful pest management program. Arthropod pest infestations may be limited by manipulation of cropping practices, but very often, particularly in monocultured systems, insecticides are required to prevent economic crop damage and yield losses. Ineffective insecticide control may be experienced if inadequate application techniques are employed in some soybean systems. Dense soybean foliage will hinder penetration of insecticides into the canopy, resulting in poor pest control, particularly the hard-to-kill species.

Modifications of cultural practices for cultural control of insects must consider aspects of the biology, ecology, behavior, and dynamics of both pest and beneficial species, and interactions with phenological stages of crop and noncrop vegetation to achieve highest levels of pest management possible, without major disruptions in the agroecosystem and the environment.

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