INFLUENCE OF CULTURAL PRACTICES AND INSECTICIDES ON DEGREE OF FEEDING DAMAGE BY SOUTHERN CORN BILLBUG, *SPHENOPHORUS CALLOSUS* (OLIVIER), TO CORN

by

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A Thesis Submitted to the Graduate Faculty
of the University of Georgia in Partial Fulfillment
of the
Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

1985

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ACKNOWLEDGEMENT

I express my sincere thanks to Dr. John N. All, my major professor for his constant support, continued guidance and advice on the entire work included in this thesis. My earnest appreciation and thanks to Dr. Preston Hunter, Head of Department and Graduate Coordinator, through whose exemplary administrative ability, I was able to complete my studies at the University of Georgia.

I also thank Dr. Ching Tsao for serving as Chairman of the reading committee and for his invaluable suggestions. My thanks are also due to Ms. Terry All for analyzing the data, Dr. A. Javid for technical services and my colleagues in the department without whom this thesis could not have become a reality.

My final thanks goes to my family - my wife, Maria and our children: Beatrice, Alice, Bob, Jimmy and Chris for their continued encouragement and patience during my long absence.

DEDICATION

Dedicated to my thoughtful parents, SAMSON and REBAH SAYIA.

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INTRODUCTION

Rabb (1972) defines Pest Management as the intelligent selection and use of pest control actions that will ensure favorable economic, ecological and sociological consequences. In developing appropriate pest control tactics, basic information on the life cycle, population dynamics and ecology of a pest is important. The Southern Corn billbug, *Sphenophorus callosus* (Olivier), is a soil pest of corn, *Zea mays* (L), but also feeds on various grasses, including nutgrass, *Cyperus* spp. (Webster 1912, Metcalf 1917).

Adult Southern Corn billbugs feed on seedling corn and produce a debilitating type damage. The injury is confined to the meristematic region of the plant. Characteristic symptoms show circular holes in the first 1-4 leaves of seedlings (appearing in line across the leaf), leaf deformation, stunting and, in severe cases, death of the plant occurs. (Metcalf 1917, DuRant 1975, Wright *et. al*. 1983).

Metcalf (1917), Satterthwait (1932) and Wright *et. al*. (1983) recommended various cultural practices for the control of the Southern Corn billbug. Early planting ensures that seedling corn will escape damage at its most vulnerable stage and use of fertilizers enables damaged plants to overcome Southern Corn billbug injury.

The present study was conducted to determine a quantitative relationship between Southern Corn billbug injury to the seedling, yield reduction, plant vigor and selected agronomic practices.

BIOLOGY OF THE SOUTHERN CORN BILLBUG

The Southern Corn billbug Sphenophorus callosus (Olivier) belongs to the order Coleoptera, Sub órder Rhynchophora, family Curculionidae and subfamily Calandrinae. This family includes various billbugs, many of which are of economic importance. They infest many crops including corn and a variety of grasses.

Southern Corn billbug was first described by Olivier in 1807 as Calendra callosus. Later, Schoenherr (1837) described a species of Sphenophorus. Since these insects resembled Sphenophorus cariosus (Olivier), Le Conte and Horn (1873) united the species and called it Sphenophorus cariosus (Olivier) and adopted callosus as a synonym. Chitterden (1906) disagreed with them and pointing out the differences between the two species and successfully separated Sphenophorus callosus from Sphenophorus cariosus.

Southern Corn billbug has a wide distribution in Eastern United States (Webster 1912, Blatchley and Leng 1916). It is found from Maine to Florida, westward to Arizona and northern Mexico and northward to Wisconsin. Satterthwait (1932) added that the Southern Corn billbug's distribution probably coincides with the range of its favorite host plant, nutgrass Cyperus spp.

The biology of Southern Corn billbug was first studied by Metcalf in 1917. It was later reviewed by Wright et. al. (1983). The adult Southern Corn billbug overwinter from October to April (Metcalf, 1917, Wright *et. al*. 1983). Satterthwait (1932), Morgan *et. al*. (1960) reported that the Southern Corn billbug over winters in broomsedge, *Andropogon virginicus* (L.), Sandspurs, *Cenchrus pauciflorus*, (L.), Bahia grass, *Paspalum hotatum* (L.) and Smut grass, *Sporobolus poiretti* (L.).

Adult Southern Corn billbugs are diurnal. Mating and oviposition in host plants starts early in May. Males seek females in secluded areas on the soil surface. A copulating female may often carry the male about until she prepares an egg cavity in host plants into which the fertilized eggs are oviposited. Fertilized eggs are deposited on 3-4 leaf stage corn and nutgrass, in the stem of the plants 2 cm below the soil surface to 4 cm high on the plant and above the soil. Eggs may also be deposited in the soil around the stem up to 2 cm below the soil surface (Metcalf 1917, Wright *et. al*. 1983).

Metcalf (1917) reported that oviposition increases between late May and August and decreases in October when adults are preparing to hibernate. Incubation of eggs requires between 77-305 hours with a mean of 132 hours before hatching, depending on the temperature and habitat. In mid May, young larvae (first and second instars) may be found feeding underground on the surface of the stalk and at the base of hosts' roots (Wright *et. al*. 1983). Highest numbers of larvae can be found between mid July and mid August. Mature larvae may also be found in late October. The fourth instar larvae develop in the stalk or roots of a host plant. Pupation takes place underground either inside or outside the host stalk (Metcalf 1917). Larvae pupating inside the stalk form cells from plant fibers.

The larva that pupates outside the stalk forms an earthen cell without plant fibers (Wright et. al. 1983). The pupa develops within 5-6 cm of the base of the stalk (Metcalf 1917), and the pupal stage takes 8-11 days, with an average of 9 days. Highest numbers of pupae are found between June and September. Some pupae over winter and emerge as adults in early spring.

There is disagreement among authorities on the life span of the Southern Corn billbug. Metcalf (1917) reported that some adult Southern Corn billbugs lived over two winters in North Carolina. Cartwright (1929) observed some Southern Corn billbugs over two summers in South Carolina. Wright et. al. (1983) disagree with the view of overwintering adult Southern Corn billbugs. They argue that although there is a possibility of overlapping generations, there is no evidence for two year adult longevity.

Southern Corn billbug host range is restricted to various grasses. Nut grasses, Cyperus spp., were reported by Webster (1912), Metcalf (1917) and Satterthwait (1932) to be favored hosts with yellow nutgrass, Cyperus esculantus (L.), most preferred. Metcalf (1917) also reported that Southern Corn billbug feeds on corn, Zea mays (L.), and rice, Oryza sativa (L.). This was supported by later researchers including Kirk (1956) and Morgan et. al. (1960). Wright et. al. (1983) added a new host plant species, Scirpus cyperinus (L.), which they stated supports larval development. They also reported that adult Southern Corn billbugs feed on a variety of greenhouse weeds: common lambsquarters, Chenopodium album (L.), fall panicum, Panicum dichotomiflorum (Michalix) and Pennsylvania smartweed, Polygonum pennsylvanicum (L.). However, survival rate is low on these plants.

The Southern Corn billbug is an economic pest of corn in the coastal plain of Georgia, South Carolina and North Carolina (Webster 1912, Metcalf 1917, Morgan et. al. 1960). In his classical study of the biology of Southern Corn billbug, Metcalf (1917) stated that larvae cause greater damage to corn than adults because they tunnel into the stalk bases thereby reducing plant growth and development. Later, DuRant (1982) attributed greater damage of corn to adult Southern Corn billbug feeding. Wright et. al. (1983) found that adult Southern Corn billbugs feed on seedling corn producing a debilitating type damage. They feed on the meristematic region of the corn seedling causing severe stunting and sometimes death.

Adult Southern Corn billbugs feeding on later stages of corn (4-8 inches high) may weaken that stock so that it produces no ears, thus causing significant loss of stand and substantial reduction in yield (Wright et. al. 1983). High losses were reported by Kirk (1956) to be due to Southern Corn billbug infestation. He observed losses of 51-96% in various infestations where no control measures were undertaken. Wright et. al. (1983) reported a yield decrease of 42.4% due to Southern Corn billbug damage in South Carolina corn fields.

All et. al. (1984) recently reported that Southern Corn billbug infestations are substantially increased in conservation tillage as compared to conventional tillage systems.

Control of Southern Corn billbug is compounded by a number of factors. Metcalf (1917) cited two of them as Southern Corn billbug's hardiness and its tendency to bury itself underground where it cannot be reached easily., He therefore recommended various cultural practices, a view that was supported by later workers including

Satterthwait (1932), Morgan et. al. (1960) and Wright et. al. (1983). From the standpoint of ease and low cost, Metcalf (1917) recommended time of planting, rotation of crops, application of fertilizers, drainage, ridging, fall and winter plowing, cultivation and destruction of native plant food.

Early planting and application of fertilizers were considered the most effective indirect control of Southern Corn billbugs. In his study, Metcalf (1917) reported that corn planted early (March) showed 6% injury while late (July) planted corn showed 94% injury. He reasoned that early planted corn gets an early start and thus able to keep ahead of the attacks of Southern Corn billbugs. Late planted corn, on the other hand, germinates at a time of greatest prevalence and activity of the adults.

Application of fertilizers enhances plant growth, thus increasing vigor and reducing the vulnerability of plants for fatal injury by Southern Corn billbugs.

Fall and winter plowing is aimed at disturbing the hibernating adults. Direct control methods involving chemicals were evaluated by Kirk (1956). Pre-plant treatments with four insecticides were tested at the rate of 2 lbs. ai per acre. Aldrin 40% WP. and G., Chlordane WP., Dieldrin WP. and Heptachlor WP., and G were used. Losses were reduced from 96.2% to 16.4%.

Morgan et. al. (1960) reported that Heptachlor 10% applied pre-emergence at the rate 2 lbs. ai per acre produced significant control of Southern Corn billbug.

DuRant (1971, 1975, 1982) has worked extensively on use of pre-emergence organophosphate and carbamate insecticides. He stated that besides Aldrin and Heptachlor (chlorinated hydrocarbons), the Southern Corn billbug is significantly controlled by: Carbofuran, Terbufos, Dursban, Dyfonate, Disulfoton, Fensulfothion and Phorate insecticides applied as pre-emergence in seed furrows and banding.

Recent developments in chemical control of Southern Corn billbug involve use of post emergence insecticides. All et. al. (1977) reported that post-emergence application of Terbufos, Fensulfothion, Chlorpyrifos and Metalkamate provide significant control of Southern Corn billbug. Further studies by DuRant (1979) and All et. al. (1984) showed that band application of Terbufos at the rate of 2.2 lbs. ai/Ha significantly reduced Southern Corn billbug injury while carbofuran applied at the same rate produced variable efficacy.

Information regarding biological control of Southern Corn billbug is scarce. Although Metcalf (1917) reported that Southern Corn billbug has no natural enemies, Krombein et. al. (1967) reported that a braconid wasp, Vipio belfragei (Cresson) parasitises Southern Corn billbug in Georgia, Indiana, and Missouri. Wright et. al. (1983) successfully reared this wasp recovered from a cocoon found in empty larval tunnels in the corn stem. A fungal pathogen, Metarrhizium Spp. is reported by Wright et. al. (1983) to parasitise Southern Corn billbug larvae.

MATERIALS AND METHODS

In 1983 an experiment was established on April 13th in a 2.0 ha field located at the University of Georgia, Southeastern Branch Experiment Station near Midville, Georgia. Corn residues from a crop the previous year and patches of crab grass, Digitaria sanguinalis (L), and nut grass, cyperus spp. (L) were covering the field at the time of planting. No tillage planting technique was used in all treatments. The cultural procedures evaluated included the use of coulter-in-row chiseling (subsoiling) planting technique and irrigation. Additionally, the insecticide terbufos was evaluated with the cultural practices. Corn in these treatments was planted in four row plots of 7m long X 0.9m row widths. The plots were arranged in a randomized complete block, split plot experimental design with four replicates; irrigation and no-irrigation were main plots and subsoiling plus terbufos, subsoiling without terbufos; no-subsoiling plus terbufos and no-subsoiling without terbufos were split plots (Little and Hills 1975).

For subsoiling a two-row planting implement called the Brown Harden Super Seeder was used. It produces a trench approximately 40cm deep in the soil (All et. al. 1984). A John Deere coulter-type, no-till planter was used to plant seed in subsoiling and no-subsoiling plots with uniform seeding rate of 5.2 X 10(4) seeds/Ha in all treatments.

Insecticide treatments involved applying terbufos granules at planting time at a rate of 0.2 kg/1000 linear m row. Granules were applied in a 18 cm wide band over the row. Overhead sprinkler irrigation was used in the irrigated treatments. Three cm water was applied 2 times in addition to 46.9 cm of rainfall that occurred in the field.

The same field used for the 1983 test was utilized in 1984. In this test rye, Secale cereale (L), was planted in October 1983 as a cover crop in selected blocks for use as no-tillage treatments. The blocks selected for conventional tillage were left fallow during the winter, plowed once 60 days before planting and afterwards harrowed four times prior to planting on April 19. Eight cultural treatments were established in a completely randomized split-split plot design. Irrigation and no irrigation were main plots, no-tillage and conventional tillage were split plots and subsoiling plus terbufos, subsoiling without terbufos, no-subsoiling plus terbufos and no subsoiling without terbufos were split-split plots (Little and Hills 1975). Cultural procedures and plot sizes were the same as described previously for irrigation, subsoiling, insecticide application and planting operations. Irrigated plots received 3cm water 7 times as needed in addition to the 48.1 cm rain water that occurred in the field during the test period.

Damage Impact Evaluations. The initial infestations produced by Southern Corn billbugs were determined when the plants were in the five leaf stage. All plants except those within 1m of treatment borders were observed and categorized as 0 = no visible damage, 1 = mild damage with circular holes in line across the leaf but no stunting due to billbug feeding (Metcalf 1917), and 2 = leaf damage and severe stunting. When the corn reached the eight leaf stage, plants were separated in four categories. These were: 1 = normal plants with no damage, 2 = plants with circular holes in line across the leaf due to past billbug feeding but no stunting, 3 = plants with leaf perforations and mild stunting, 4 = plants with severe leaf damage, stunting, and/or succoring. Ten plants in each category were selected in each plot and tagged for later evaluation.

When the corn reached the tasseling/silking stage all tagged plants were examined and evaluated for mortality, plant height, and basal diameter. Tagged plants were harvested and the ears weighed. Additionally, overall yield in each treatment was determined by harvesting all the ears in the middle two rows of each plot. Grain weights were standardized at 15.5% moisture content. All data were analyzed by standard analysis of variance procedures (Little and Hills, 1975).

RESULTS AND DISCUSSION

Damage by the Southern Corn billbug in seedling (5-leaf stage) corn was uniformly high in the field during 1983 (Table 1). A trend for a higher infestation was apparent in non-irrigated plots as compared to irrigated treatments, but this was not statistically significant. Also, no overall differences between subsoiling and no subsoiling treatments occurred in Southern Corn billbug damage to young seedlings. The insecticide terbufos had no suppression of damage in treated plots as compared to non-insecticide treatments, and this was different from results of other workers (DuRant 1975, All and Jellum 1977, All et. al. 1984). No interaction among the treatments was apparent at this stage of corn growth in the field.

Table 2 shows that a tremendous infestation of billbugs occurred in the field in 1984 with 100% of the plants infested in certain plots. The infestations were significantly higher in the no-tillage treatments, verifying the results of All et. al. (1984). Again, there was a trend for higher numbers of infested plants in irrigated treatments, but this was not statistically significant. Insecticide treatment was not effective as occurred in 1983. There was no difference between subsoiling and no subsoiling in the number of damaged plants at this plant stage. In 1984 the lowest numbers of infested plants occurred in non-irrigated, conventional tillage plots and was significantly different from irrigated, conventional tillage treatments. This suggests that the irrigation had a stimulative effect on Southern Corn billbug populations during the period that adult populations were initiating exponential growth in numbers. No other interactions among treatments were apparent at the 5-leaf stage of plant development.

When plants reached the 8-10 leaf stage (whorl stage) of development, distinct differences in the level of the debilitory effect that Southern Corn billbug injury produces in plants were apparent in 1983 (Table 3). Considered individually, neither irrigation or subsoiling influenced the severity of corn stunting, but the number of severely damaged (category 4) plants was significantly reduced in all insecticide treatments. The influence of individual treatments will be discussed by category.

Category 1 (undamaged plants). These were uninjured plants, and parameters such as height and stalk diameter of plants in this category were the standard of comparison that other plants were judged by in the the other categories. The number of uninjured plants was similar in irrigated as compared to non-irrigated plots and in subsoiling versus no subsoiling (Table 3). Overall, there was a significant difference in terbufos treatments as compared to no-insecticide plots. This indicates that Southern Corn billbug feeding damage increased from the sampling of damage in the 5-leaf stage of corn development, and that the insecticide was reducing the intensity of injury. The data suggest a positive interaction occurred with insecticide and subsoiling in both irrigated and non-irrigated treatment. This parallels the observation of All et. al. (1984) that subsoiling and terbufos had a potentiated interaction when corn was under drought stress.

Category 2 (leaf perforations but no stunting). This category represents mild injury by Southern Corn billbugs, probably to very young seedlings, that is apparent as symmetrical perforations on the leaves. In this category, there is no difference in plant height or appearance from non-damaged plants (category 1). In 1983, there was no significant difference in the percentage of plants in this category in any of the treatments (Table 3).

Category 3 (leaf perforations and mild stunting). This category was designated because observations over several years of Southern Corn billbug damage to corn indicate that some plants show moderate stunting, but are not as severely deformed as those designated for category 4. These plants sometimes grow normally and produce ears. In the 1983 test there was no significant difference in the mean percent of plants in category 3.

Category 4 (leaf perforations and severe stunting). These are plants in which Southern Corn billbug feeding has severely damaged the growing bud of a corn seedling, resulting in severe stunting and sometimes death of plants. Observations indicate that few of these plants ever produce ears. Overall, no difference in irrigated and non-irrigated plots or subsoiling and no subsoiling treatments occurred. The numbers of category 4 plants were significantly reduced in insecticide treatments. No significant interaction among treatments occurred, except in irrigated plots with insecticide plus subsoiling as compared to no insecticide and no subsoiling.

In 1984 similar trends to the 1983 results were evident in overall effects for irrigation and subsoiling, i.e. the differences were not significant (Table 4). The beneficial effect of terbufos was not apparent in 1984 as compared to 1983 results. No-tillage was compared to conventional tillage in the 1984 tests, and at the time that the damage ratings were made in the no-tillage plots many plants had died. Overall, the stand had been reduced by at least 50% in all the no-tillage treatments; whereas, in conventional tillage plots, less than 5 % of the stand had been killed due to Southern Corn billbug injury. Thus, the data taken in no-tillage plots were done on surviving plants and does not totally reflect the difference in the intensity of the infestation in no-tillage as compared to conventional tillage treatments.

Category 1. No overall effect of irrigation, subsoiling or insecticide were evident. The percent of undamaged plants was significantly less in the no-tillage treatments as compared to conventional tillage (Table 4). There was no interaction evident among treatments for category 1 plants.

Category 2. Results paralleled those of the category 1 plants. No significant differences occurred among the treatments.

Category 3. Overall, the number of plants showing slight to moderate stunting were greater in no-tillage as compared to conventional tillage plots and in irrigated as compared to non-irrigated treatments (Table 4). No consistent effect of subsoiling or insecticide treatment were evident for category 3 plants. Analysis of the data demonstrates that significant interaction among certain treatments occurred. For example, fewer category 3 plants occurred in irrigated conventional tillage treatments. Also, fewer plants occurred in subsoiling plus terbufos treatments in no-tillage plots.

Category 4. A significantly higher number of severely stunted plants were present in no-tillage as compared to conventional tillage treatments. No difference between irrigated and non-irrigated treatments was apparent and no trend for fewer numbers of these severely stunted plants was evident in subsoiling as compared to no subsoiling. In general, there were fewer category 4 plants in the insecticide treatments, but the data was variable. No consistent trend for interaction among other cultural treatments was apparent (Table 4).

When the plants reached the silking/tasseling stage, plants that had been tagged in the four damage categories were evaluated to determine if they had died and if not, height, stem diameter, and ear weight were determined. In 1983 a linear increase in mortality occurred between categories 1-4 during the period of initial categorization (5-leaf stage) to the silking/tasseling (Table 11). Little mortality occurred in category 1, except under irrigation it was found that some plants were killed in non-insecticide treatments in both subsoiling and no-subsoiling plots. This indicates that under certain circumstances the Southern Corn billbug can produce substantial injury to plants after the tasseling stage, and that terbufos residues may be present at that time to prevent damage.

The same result occurred with the category 2 plants in the irrigated plots. Significantly greater mortality occurred in the non-insecticide treatments in both subsoiling and no subsoiling plots. The influence of terbufos was not apparent in the non-irrigated plots, similar mortality occurred in all the treatments (Table 11). There were no major differences among treatments in the percent mortality for categories 3 and 4.

In 1984 the corn was virtually destroyed in all no-tillage treatments, thus analysis of data for the tagged plants was possible only in the conventional tillage plots. A similar trend as in 1983 for progressively higher mortality in categories 1-4 was evident. Higher, overall mortality occurred in all four categories during 1984, reflecting the more intense infestation that occurred early in the season as compared to 1983 (Table 12). In category 1, no mortality occurred under irrigation; whereas, in non-irrigated plots, high mortality occurred in the non-insecticide plots of both subsoiling and no subsoiling. No consistent trends for treatment interactions in level of mortality were evident in categories 2, 3, and 4.

In 1983 the plant height was similar in category 1 and 2 treatments; category 3 was intermediated and category 4 had substantially smaller sized plants (Table 5). DuRant (1982) demonstrated that the severity of Southern Corn billbug feeding was negatively correlated with plant height. No overall difference between irrigated and non-irrigated treatments occurred within the categories. A trend for greater plant height in subsoiling as compared to no subsoiling treatments occurred within all the damage categories, but this was not statistically significant. Plants were taller in most of the insecticide plots, but this was generally not a statistically significant interaction with other treatments within each of the categories.

In 1984 there was a linear decrease in plant height with increase in level of damage (categories 1-4) and plants in category 4 were over 50 cm shorter than the category 1 plants (Table 6). Irrigation had a substantial effect on plant growth in all categories and plants were

50-60 cm taller in all treatments as compared to the non-irrigated plots. Plants were significantly taller in the insecticide treatments in categories 2-4, but the differences between terbufos treated and untreated plots was not significantly different in category 1. Few plants that had been tagged as category 4 in the tasseling stage survived to the silking/tasseling period of growth. For those that did survive, there was no significant difference in plant height among the treatments.

Stem diameter, along with plant height, reflects general plant vigor, and in 1983 a linear decrease in diameter occurred in each succeeding category of damage (Table 7). However, within the different categories, there were no differences between plots, except in the irrigated, no subsoiling, no insecticide treatment of category 1. In the 1984 test the same general relationships were apparent, except that categories 1 and 2 plants had similar stem diameter, whereas, categories 3 and 4 were similar; both categories had significantly smaller stem thickness than the first two categories (Table 8). No substantial differences occurred between treatments within the four categories paralleling results of 1983.

The weight of ears harvested from plants tagged in the four categories paralleled the relationships observed for plant height and stem diameter (Table 9). A linear decrease in mean ear weight occurred with increase in damage rating, and this amounted to approximately a 25 g decrease in each succeeding category. A trend for decreased weight in insecticide treatments occurred, but this was significant only in category 1 in irrigated no subsoiling treatments. No other treatment interactions were apparent within the damage categories. A similar trend occurred in the 1984 test, except the magnitude of difference was greater between the categories (Table 10). The decrease in ear weight was approximately 50g in each succeeding category during 1984. No ears were produced for category 3 plants in three of the non-irrigated treatments and for category 4 plants in three irrigated and one non-irrigated plot. This reflected the greater infestation that occurred in 1984 as compared to 1983. No differences between treatments occurred within categories 1-3 and, thus, were similar to the results of 1983. In category 4 fewer plants survived to produce ears and there was less competition among individual plots for soil moistures and nutrients. This explains the greater individual weight of ears in certain of the treatments. Thus comparison of mean ear weight among the different treatments is not possible.

Overall yield is the most important parameter reflecting the ability of plants to grow in the various cultural treatments while under intensive Southern Corn billbug infestations. In 1983 overall grain yield was higher in the non-irrigated as compared to irrigated treatments, and this reflects the higher initial infestation that occurred in the irrigated plots (Table 13). Subsoiling had higher overall yield than the no subsoiling treatments. The overall effect of using terbufos also was apparent with increased yields occurring in the insecticide treatments as compared to non-treated plots. The data indicates a positive interaction between insecticide and subsoiling in both irrigated and non-irrigated as was reported by All et. al. (1984). In the 1984 test the devastating impact of the Southern Corn billbug infestation in no-tillage treatments was reflected by the lack of yield in virtually all treatments (Table 14). In the conventional tillage plots, yield was highest in insecticide treatments, but no effect of irrigation or subsoiling was apparent. No interaction between cultural treatments was apparent.

TABLE 1

Mean percent damage by Southern Corn billbug on 5-leaf stage corn plants during 1983.

Treatment*	Mean % Damage
I + SS + IS	65.9 b
I + SS + NIS	45.6 a
I + NSS + IS	75.1 bc
I + NSS + NIS	69.5 bc
Mean	64.0 b
NI + SS + IS	77.7 bc
NI + SS + NIS	69.6 bc
NI + NSS + IS	83.6 c
NI + NSS + NIS	76.9 bc
Mean	76.8

* I = irrigation; NI = no irrigation; SS = subsoiling; NSS = no subsoiling; IS = insecticide (terbufos @ 2 lbs. ai/A); NIS = no insecticide.

Means followed by same letter are not significantly (P less than 0.05) different by Duncan's Multiple Range Analysis.

TABLE 2

Mean percent feeding damage by Southern Corn billbug on 5-leaf stage corn plants during 1984.

Treatment*	Mean % Damage
I + CT + SS + IS	94.0 bc
I + CT + SS + NIS	90.0 bc
I + CT + NSS + IS	89.8 bc
I + CT + NSS + NIS	91.2 bc
Mean	91.3
I + NT + SS + IS	100.0 c
I + NT + SS + NIS	92.4 c
I + NT + NSS + IS	100.0 c
I + NT + NSS + NIS	88.3 bc
Mean	95.3
NI + CT + SS + IS	37.4 a
NI + CT + SS + NIS	45.2 a
NI + CT + NSS + IS	33.8 a
NI + CT + NSS + NIS	53.6 ab
Mean	42.5
NI + NT + SS + IS	94.0 bc
NI + NT + SS + NIS	64.4 ab
NI + NT + NSS + IS	90.3 bc
NI + NT + NSS + NIS	87.6 bc
Mean	84.1
Overall Mean	78.3

* I = irrigation; NI = no irrigation; SS = subsoiling; NSS = no subsoiling; IS = insecticide (terbufos @ 2 lbs. ai/A); NIS = no insecticide.

Means followed by same letter are not significantly (P less than 0.05) different by Duncan's Multiple Range Analysis.

TABLE 3

Severity of injury to whorl stage corn (8 leaf stage) produced by the Southern Corn billbug in 1983.

	% Plants Without Damage	% Plants With Varying Degrees of Damage**		
Treatment*	Category 1	Category 2	Category 3	Category 4
I + SS + IS	49.0 b	29.5 a	8.8 b	11.8 bcd
I + SS + NIS	29.3 c	25.5 a	15.3 ab	29.1 ab
I + NSS + IS	46.3 bc	28.6 a	12.1 b	12.9 bcd
I + NSS + NIS	27.5 c	34.8 a	12.0 b	32.4 a
Mean	38.0	29.6	12.0	21.6
NI + SS + IS	68.4 a	22.5 a	7.6 b	1.3 d
NI + SS + NIS	43.6 bc	28.5 a	12.1 b	15.1 bcd
NI + NSS + IS	52.6 ab	26.3 a	11.7 b	9.3 cd
NI + NSS + NIS	34.2 bc	26.4 a	21.4 a	21.1 abc
Mean	49.7	25.9	13.2	11.7
Overall Mean	43.5	27.8	12.7	16.6

* I = irrigation; NI = no irrigation; SS = subsoiling; NSS = no subsoiling; IS = insecticide (Terbufos at 2 lbs. ai/A); NIS = no insecticide.
** Categories: 1 = no leaf damage; 2 = leaf perforations from billbug but no stunting; 3 = leaf perforations and mild stunting; 4 = severe leaf feeding, and severe stunting.

Means followed by same letter are not significantly (P less than 0.05) different by Duncan's Miltiple Range Analysis.

TABLE 4

Severity of injury to whorl stage corn (8 leaf stage) produced by the Southern Corn billbug in 1984.

Treatment*	% Plants Without Damage	% Plants With Varying Degrees of Damage**		
	Category 1	Category 2	Category 3	Category 4
I + CT + SS + IS	66.3 a	17.9 ab	13.4 bc	2.2 cd
I + CT + SS + NIS	48.2 abc	10.0 b	15.4 abc	26.2 abcd
I + CT + NSS + IS	78.7 a	14.3 b	6.8 c	0.0 d
I + CT + NSS + NIS	73.0 a	13.2 b	5.8 c	7.7 cd
Mean	66.5	13.9	10.4	9.0
I + NT + SS + IS	32.9 bcd	28.8 ab	7.5 c	30.5 abcd
I + NT + SS + NIS	2.0 d	6.0 b	39.6 ab	52.2 a
I + NT + NSS + IS	4.1 d	12.1 b	16.6 abc	44.5 a
I + NT + NSS + NIS	28.8 cd	37.7 a	2.2 c	31.1 abc
Mean	16.9	21.2	16.5	39.6
NI + CT + SS + IS	81.1 a	7.2 b	10.9 c	1.6
NI + CT + SS + NIS	63.5 ab	11,6 b	18.2 abc	6.5
NI + CT + NSS + IS	79.3 a	12.6 b	5.9 c	2.1 cd
NI + CT + NSS + NIS	69.1 a	6.9 b	39.6 ab	9.9 bcd
Mean	73.3	9.6	18.7	5.0
NI + NT + SS + IS	15.2 cd	15.8 b	20.2 abc	48.6 a
NI + NT + SS + NIS	18.1 cd	26.0 ab	42.7 a	13.1 bcd
NI + NT + NSS + IS	32.6 bcd	18.4 ab	10.5 c	38.3 ab
NI + NT + NSS + NIS	22.2 cd	8.3 b	24.4 abc	45.0 a
Mean	22.0	17.1	24.5	36.3
Overall Mean	45.3	15.2	16.0	21.9

* I = irrigation; NI = no irrigation; SS = subsoiling; NSS = no subsoiling; IS = insecticide (terbufos @ 2 lbs. ai/A); NIS = no insecticide.

** Categories: 1 = no damage; 2 = leaf perforations from billbug feeding; 3 = leaf perforations and mild stunting; 4 = severe leaf feeding and stunting.

Means followed by same letter are not significantly (P less than 0.05) different by Duncan's Multiple Range Analysis.

TABLE 5

Mean height (cms) of corn plants in the tasseling stage grown under various cultural and chemical treatments with varying degrees of Southern Corn billbug feeding damage in 1983.

	MEAN HEIGHT OF THE PLANTS			
	Without Damage	With Varying Degrees of Damage**		
Treatment*	Category 1	Category 2	Category 3	Category 4
I + SS + IS	203.2 a	199.1 a	167.6 a	148.9 a
I + SS + NIS	197.9 a	183.9 ab	168.6 a	127.8 a
I + NSS + IS	196.1 a	181.4 ab	161.9 a	126.7 a
I + NSS + NIS	141.8 b	170.6 ab	137.5 a	123.3 a
Mean	184.5	183.8	158.9	131.7
NI + SS + IS	201.5 a	199.7 a	142.7 a	135.2 a
NI + SS + NIS	206.4 a	196.7 a	161.8 a	151.1 a
NI + NSS + IS	190.6 a	166.8 b	142.9 a	111.8 a
NI + NSS + NIS	181.3 a	166.1 b	167.3 a	154.0 a
Mean	195.0	182.3	153.7	138.0
Overall Mean	189.8	182.6	156.7	134.3

* I = irrigation; NI = no irrigation; SS = subsoiling; NSS = no subsoiling; IS = insecticide (Terbufos at 2 lbs. ai/A); NIS = no insecticide.

** Categories: 1 = no leaf damage; 2 = leaf perforations from billbug feeding; 3 = leaf perforations and mild stunting; 4 = severe leaf feeding stunting.

Means followed by same letter are not significantly (P less than 0.05) different by Duncan's Multiple Range Analysis.

TABLE 6

Mean heights (cms) of corn plants in the tasseling stage grown under various cultural and chemical treatments with varying degrees of Southern Corn billbug feeding damage in 1984.

	MEAN HEIGHTS OF THE PLANTS			
	Without Damage	With Varying Degrees of Damage**		
Treatment*	Category 1	Category 2	Category 3	Category 4
I + CT + SS + IS	198.8 ab	169.4 ab	149.0 ab	-----
I + CT + SS + NIS	189.5 ab	170.4 ab	145.5 abc	143.1 a
I + CT + NSS + IS	204.9 a	172.7 ab	180.6 a	137.2 a
I + CT + NSS + NIS	188.3 ab	175.0 ab	172.7 a	-----
Mean	195.4	171.9	161.9	140.2
NI + CT + SS + IS	131.8 c	122.5 b	140.7 abc	137.0 a
NI + CT + SS + NIS	155.5 bc	41.8 c	91.4 bc	68.3 a
NI + CT + NSS + IS	160.7 abc	190.5 a	-----	-----
NI + CT + NSS + NIS	128.1 c	107.9 b	78.1 c	86.0 a
Mean	144.0	115.7	103.4	97.1
Overall Mean	169.7	143.8	136.9	114.3

* I = irrigation; NI = no irrigation; SS = subsoiling; NSS = no subsoiling; IS = insecticide (terbufos @ 2 lbs. ai/A); NIS = no insecticide.

** Categories: 1 = no damage; 2 = leaf perforations from billbug feeding; 3 = leaf perforations and mild stunting; 4 = severe leaf feeding and stunting.

Means followed by same letter are not significantly (P less than 0.05) different by Duncan's Multiple Range Analysis.

TABLE 7

Mean stem thickness (cms)* of corn plants in the tasseling stage grown under various cultural and chemical treatments with varying degrees of Southern Corn billbug feeding damage in 1983.

	MEAN STEM DIAMETER OF THE PLANTS			
	Without Damage	With Varying Degrees of Damage***		
Treatment**	Category 1	Category 2	Category 3	Category 4
I + SS + IS	2.0 ab	1.9 a	1.6 a	1.3 a
I + SS + NIS	2.0 a	1.8 a	1.6 a	1.3 a
I + NSS + IS	2.0 a	1.8 a	1.6 a	1.2 a
I + NSS + NIS	1.7 b	1.8 a	1.6 a	1.3 a
Mean	1.9	1.8	1.6	1.3
NI + SS + IS	2.0 a	1.9 a	1.4 a	1.3 a
NI + SS + NIS	2.0 a	1.9 a	1.5 a	1.3 a
NI + NSS + IS	1.9 ab	1.7 a	1.5 a	1.3 a
NI + NSS + NIS	1.9 ab	1.8 a	1.6 a	1.4 a
Mean	1.9	1.8	1.5	1.3
Overall Mean	1.9	1.8	1.5	1.3

* Stem diameter was measured 2.5 cms above the ground.
** I = irrigation; NI = no irrigation; SS = subsoiling; NSS = no subsoiling; IS = insecticide (Terbufos at 2 lbs. ai/A); NIS = no insecticide.
*** Categories: 1 = no leaf damage; 2 = leaf perforations from billbug feeding; 3 = leaf perforations and mild stunting; 4 = severe leaf feeding and stunting.

Means followed by same letter are not significantly (P less than 0.05) different by Duncan's Multiple Range Analysis.

TABLE 8

Mean stem thickness (cms)* of corn plants in the tasseling stage grown under various cultural and chemical treatments with varying degrees of Southern Corn billbug feeding damage in 1984.

	MEAN STEM DIAMETER OF THE PLANTS			
	Without Damage	With Varying Degrees of Damage***		
Treatment**	Category 1	Category 2	Category 3	Category 4
I + CT + SS + IS	1.8 ab	1.6 b	1.0 a	---
I + CT + SS + NIS	2.4 ab	1.8 a	1.5 a	1.3 a
I + CT + NSS + IS	2.2 ab	1.8 a	1.4 a	1.3 a
I + CT + NSS + NIS	2.7 a	4.3 a	1.6 a	---
Mean	2.3	3.4	1.4	1.3
NI + CT + SS + IS	2.0 ab	1.6 a	1.4 a	1.1 a
NI + CT + SS + NIS	2.3 ab	2.1 a	1.5 a	1.1 a
NI + CT + NSS + IS	2.4 ab	2.5 a	---	---
NI + CT + NSS + NIS	2.4 ab	2.6 a	1.2 a	0.9 a
Mean	2.3	2.2	1.4	1.1
Overall Mean	2.3	2.3	1.4	1.2

* Stem diameter was measured 2.5 cms. above the ground.
** I = irrigation; NI = no irrigation; SS = subsoiling; NSS = no subsoiling; IS = insecticide (terbufos @ 2 lbs. ai/A); NIS = no insecticide.
*** Categories: 1 = no damage; 2 = leaf perforations from billbug feeding; 3 = leaf perforations and mild stunting; 4 = severe leaf feeding and stunting.

Means followed by same letter are not significantly (P less than 0.05) different by Duncan's Multiple Range Analysis.

TABLE 9

Mean ear weight (gms.) from corn plants in the tasseling stage grown under various cultural and chemical treatments with varying degrees of Southern Corn billbug feeding damage in 1983.

	MEAN EAR WEIGHT OF THE PLANTS			
	Without Damage	With Varying Degrees of Damage**		
Treatment*	Category 1	Category 2	Category 3	Category 4
I + SS + IS	150.6 a	124.0 a	91.5 a	46.6 b
I + SS + NIS	152.8 a	101.7 a	104.0 a	47.5 b
I + NSS + IS	153.3 a	116.7 a	102.0 a	56.0 ab
I + NSS + NIS	81.6 b	109.3 a	64.8 a	38.5 b
Mean	134.0	112.9	90.6	47.2
NI + SS + IS	180.6 a	142.9 a	114.7 a	101.0 ab
NI + SS + NIS	154.1 a	149.8 a	84.8 a	132.4 a
NI + NSS + IS	166.2 a	127.2 a	84.2 a	88.1 ab
NI + NSS + NIS	165.0 a	129.7 a	115.0 a	36.1 b
Mean	166.5	137.4	99.7	89.4
Overall Mean	150.5	125.2	94.5	68.3

* I = irrigation; NI = no irrigation; SS = subsoiling; NSS = no subsoiling; IS = insecticide (Terbufos at 2 lbs. ai/A); NIS = no insecticide.

** Categories: 1 = no leaf damage; 2 = leaf perforations from billbug feeding; 3 = leaf perforations and mild stunting; 4 = severe leaf feeding and stunting.

Means followed by same letter are not significantly (P less than 0.05) different by Duncan's Miltiple Range Analysis.

TABLE 10

Mean ear weight (gms.) from corn plants in the tasseling stage grown under various cultural and chemical treatments with varying degrees of Southern Corn billbug feeding damage in 1984.

	MEAN EAR WEIGHT OF THE PLANTS			
	Without Damage	With Varying Degrees of Damage**		
Treatment*	Category 1	Category 2	Category 3	Category 4
I + CT + SS + IS	170.7 a	111.9 a	33.1 a	----
I + CT + SS + NIS	164.7 a	130.7 a	91.5 a	190.0 b
I + CT + NSS + IS	271.3 a	195.2 a	109.7 a	----
I + CT + NSS + NIS	173.7 a	222.0 a	106.8 a	----
Mean	195.1	165.0	82.3	190.0
NI + CT + SS + IS	204.4 a	138.6 a	118.1 a	215.0 a
NI + CT + SS + NIS	214.1 a	117.0 a	----	129.0 c
NI + CT + NSS + IS	185.9 a	212.0 a	----	----
NI + CT + NSS + NIS	167.4 a	117.0 a	----	85.0 d
Mean	193.0	146.2	118.1	107.3
Overall Mean	190.0	155.6	91.9	154.8

* I = irrigation; NI = no irrigation; SS = subsoiling; NSS = no subsoiling; IS = insecticide (terbufos @ 2 lbs. ai/A); NIS = no insecticide.

** Categories: 1 = no damage; 2 = leaf perforations from billbug feeding; 3 = leaf perforations and mild stunting; 4 = severe leaf feeding and stunting.

Means followed by same letter are not significantly (P less than 0.05) different by Duncan's Multiple Range Analysis.

TABLE 11

Mean percent mortality of corn plants in the tasseling stage grown under various cultural and chemical treatments with varying degrees of Southern Corn billbug feeding damage in 1983.

	MEAN PERCENT MORTALITY OF THE PLANTS			
	Without Damage	With Varying Degrees of Damage**		
Treatment*	Category 1	Category 2	Category 3	Category 4
I + SS + IS	0.0 b	0.0 b	10.0 ab	35.0 a
I + SS + NIS	10.0 ab	10.0 ab	15.0 ab	50.0 a
I + NSS + IS	0.0 b	0.0 b	10.0 ab	30.0 a
I + NSS + NIS	20.0 a	20.0 a	30.0 a	25.0 a
Mean	15.0	15.0	16.3	35.0
NI + SS + IS	0.0 b	5.0 ab	13.3 ab	45.0 a
NI + SS + NIS	0.0 b	5.0 ab	15.0 ab	50.0 a
NI + NSS + IS	0.0 b	2.5 b	30.0 a	35.0 a
NI + NSS + NIS	0.0 b	10.0 ab	5.0 b	35.0 a
Mean	0.0	5.6	15.8	41.3
Overall Mean	3.7	6.5	16.1	38.1

* I = irrigation; NI = no irrigation; SS = subsoiling; NSS = no subsoiling; IS = insecticide (Terbufos at 2 lbs. ai/A); NIS = no insecticide.
** Categories: 1 = no leaf damage; 2 = leaf perforations from billbug feeding; 3 = leaf perforations and mild stunting; 4 = severe leaf feeding and stunting.

Means followed by same letter are not significantly (P less than 0.05) different by Duncan's Miltiple Range Analysis.

TABLE 12

Mean percent mortality of the plants in the tasseling stage grown under various cultural and chemical treatments with varying degrees of Southern Corn billbug feeding damage in 1984.

Treatment*	MEAN PERCENT MORTALITY OF THE PLANTS**			
	Without Damage	With Varying Degrees of Damage		
	Category 1	Category 2	Category 3	Category 4
I + CT + SS + IS	0.0 d	0.0 b	56.2 ab	100.0 a
I + CT + SS + NIS	0.0 d	18.7 ab	25.0 b	81.2 ab
I + CT + NSS + IS	0.0 d	27.0 ab	45.8 ab	100.0 a
I + CT + NSS + NIS	0.0 d	0.0 b	66.6 ab	100.0 a
Mean	0.0	22.8	48.4	95.3
NI + CT + SS + IS	0.0 d	75.0 a	50.0 ab	87.5 a
NI + CT + SS + NIS	25.0 cd	75.0 a	75.0 ab	58.3 b
NI + CT + NSS + IS	0.0 d	75.0 a	100.0 a	100.0 a
NI + CT + NSS + NIS	37.5 bcd	31.2 ab	62.5 ab	87.5 a
Mean	31.3	64.0	71.9	82.8
Overall Mean	31.3	46.8	52.6	89.3

* I = irrigation; NI = no irrigation; SS = subsoiling; NSS = no subsoiling; IS = insecticide (terbufos @ 2 lbs. ai/A); NIS = no insecticide.
** Categories: 1 = no damage; 2 = leaf perforations from billbug feeding; 3 = leaf perforations and mild stunting; 4 = severe leaf feeding and stunting.

Means followed by same letter are not significantly (P less than 0.05) different by Duncan's Multiple Range Analysis.

TABLE 13

Grain yield from different treatments for control of Southern Corn billbug on corn plants during 1983.

Treatment*	Yield kgs/plot
I + SS + IS	3.0 ab
I + SS + NIS	2.7 bc
I + NSS + IS	3.0 b
I + NSS + NIS	1.5 c
Mean	2.7
NI + SS + IS	5.1 a
NI + SS + NIS	4.7 a
NI + NSS + IS	4.1 ab
NI + NSS + NIS	2.8 bc
Mean	4.1
Overall Mean	3.5

* I = irrigation; NI = no irrigation; SS = subsoiling; NSS = no subsoiling; IS = insecticide (terbufos @ 2 lbs. ai/A); NIS = no insecticide.

Means followed by same letter are not significantly (P less than 0.05) different by Duncan's Multiple Range Analysis.

TABLE 14

Grain yield (kgs.) from different treatments for control of Southern Corn billbug on corn plants during 1984.

Treatment*	Yield kgs/plot
I + CT + SS + IS	4.3 b
I + CT + SS + NIS	2.3 d
I + CT + NSS + IS	5.8 a
I + CT + NSS + NIS	0.4 ef
Mean	3.2
I + NT + SS + IS	0.1 f
I + NT + SS + NIS	0.0 f
I + NT + NSS + IS	0.0 f
I + NT + NSS + NIS	0.0 f
Mean	0.1
NI + CT + SS + IS	2.7 cd
NI + CT + SS + NIS	1.8 de
NI + CT + NSS + IS	1.7 de
NI + CT + NSS + NIS	1.7 de
Mean	2.0
NI + NT + SS + IS	0.3 ef
NI + NT + SS + NIS	0.0 f
NI + NT + NSS + IS	1.2 def
NI + NT + NSS + NIS	0.3 ef
Mean	0.6
Overall Mean	1.9

* I = irrigation; NI = no irrigation; SS = subsoiling; NSS = no subsoiling; IS = insecticide (terbufos @ 2 lbs. ai/A); NIS = no insecticide.

Means followed by same letter are not significantly (P less than 0.05) different by Duncan's Multiple Range Analysis.

SUMMARY

In summary, these tests demonstrate that the degree of damage produced by the Southern Corn billbugs to corn is influenced by various cropping practices. During 1983, treatments were irrigation, subsoiling and use of terbufos.

At the 5-leaf stage of the crop when leaves were showing perforations caused by Southern Corn billbug feeding, the corn plants under irrigation required terbufos for protection irrespective of subsoiling or no-subsoiling. Under non-irrigated conditions, neither subsoiling nor insecticide significantly changed the number of damaged plants in any treatment indicating that these cultural practices have no effects in controlling Southern Corn billbugs.

At the 8-leaf stage, the plants had developed varying degrees of damage and were classified into categories 1 to 4. Stunting, due to severe feeding damage, was observed in categories 3 and 4. The mean percent of plants with no apparent feeding damage was higher in terbufos treated plots under irrigation as well as non-irrigation plots demonstrating the effectiveness of terbufos in reducing Southern Corn billbug injury in either irrigated or non-irrigated plots (All et. al. 1984). Furthermore, there was no clear cut difference in Southern Corn billbug feeding damage between corn plants in subsoiling and no-subsoiling, probably because subsoiling had no influence on control of Southern Corn billbug populations. A higher percentage of plants

without any apparent feeding damage occurred under no irrigation, indicating that irrigation enhanced crop stand (Camp et. al. 1981), thus inviting more Southern Corn billbug feeding damage.

Most combination of treatments had no significantly different percentage of plants with Southern Corn billbug feeding damage in categories 2, 3 and 4. There were, however, a few exceptions in which terbufos was not included in their treatments demonstrating the protective influence provided by terbufos for at least two months after application. These observations compare well with investigations by DuRant (1975), All and Jellum (1979) in which terbufos applied at similar rates controlled Southern Corn billbug in field corn.

In general, there was a progressive increase in mean percent of damaged plants from categories 2 to 4 in most of the treatments. Category 2 occurs in the seedling stage, and, possibly, Southern Corn billbugs move over large areas after initial infestation in search of germinating plants and this results in a higher percent of such damage. As plants grow, Southern Corn billbugs may congregate on fewer plants causing severe feeding damage with varying degrees of stunting.

Mean yields of individual plants under non-irrigated conditions were higher as compared to irrigated. This indicates the debilitating effects Southern Corn billbug feeding damage have on corn in irrigated plots which appeared to attract higher Southern Corn billbug populations.

With two exceptions, the mortalities of the plants under the various combinations of treatments were not significantly different. There was a progressive increase in mortality from categories 1 to 4. A comparison of the mortalities of plants in categories 2 and 4 showed higher percentages in non-irrigated plots as compared to irrigated plots especially in category 4. Considerable reduction in mortality could be explained by increased insecticide effectiveness in moist sandy soils (Harris 1967). There was also a positive relationship between severity of injury and mortality to corn by Southern Corn billbug feeding with reduction in stand and the number of succorred (deformed) plants (Morgan and Beckham 1960). The most severely damaged plants (category 4) showed the highest mortality rates.

During 1983, there was no clear cut difference in yields per plot under different combination of treatments.

In 1984, conventional tillage was studied along with other cultural methods experimented during 1983.

At the 5-leaf stage under irrigation, conventional tillage had significantly reduced damages as compared to no-tillage, verifying results of All et. al. (1984). The devastation in no-tillage increased to the point where corn production was eliminated for practical purposes and this was irrespective of any of the cultural practices.

Conventional tillage has been reported to disturb over wintering adults of the Southern Corn billbug and thus suppressing populations (Metcalf 1917, Satterthwait 1932, Wright et. al. 1983). Possibly, irrigation in combination with conventional tillage enhances population suppression.

Owing to poor stand of the crop in no-tillage plots, mean height, diameter, yield and mortality of individual plants were studied in conventional tillage. In general, plants receiving irrigation were taller than those under no irrigation indicating that irrigation enhances plant growth (Knight 1965, DuRant 1982). There was a gradual decrease in plant height and stem diameter from categories 2 to 4.

The ear weight was not significantly different in any combination of treatments. Individual plant mortalities were considerably higher in categories 2 and 3. Yield per plot was not consistent in the treatments. However, yields were higher in conventional tillage plots which received irrigation. The higher yields are attributed to the positive effects of the agronomic practices on plant growth and on decreased Southern Corn billbug feeding damage.

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