Special Bulletin 89-1
July 1989

PROCEEDINGS

1989 Southern Conservation Tillage Conference

Tallahassee, Florida

INTEGRATED PEST MANAGEMENT

Institute of Food and Agricultural Science
University of Florida

This publication was funded by The National Fertilizer DevelopmentCenter of TVA, Muscle Shoals, **Alabama**

Proceedings

1989 Southern Conservation Tillage Conference

Tallahassee, Florida
July 12-13, 1989

Published in cooperation with the Institute of Food and Agricultural Science

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Foreward

Historically, the first no-till conference was hosted by the Georgia Experiment Station at Griffin in 1978, with seven southeastern states as participants. The Conference was expanded to include all 13 states in the Southern Region in 1985. In 1987, the steering committee voted to change the conference title to **Conservation Tillage Conference.** The primary objective thus became the promotion of conservation production systems, not just no-till, by providing a communication link between various agencies and personnel interested in resource conservation.

Excessive tillage and poor tillage practices are the primary cause of soil erosion from farmland and contributes to surface water pollution with soil, fertilizer, and pesticides. Agriculture is no longer exempt from accountability of actions that may degrade the environment. Conservation tillage is one way to reduce erosion, it is not new, but it was not until 1970 (sparked by the energy crunch) that minimum tillage planters were perfected to the point where they could be used successfully to perform deep tillage in the row while leaving row middles undisturbed in the compacted, sandy soils of the Coastal Plain.

The 1989 conference theme, "Conservation Farming: Preserving Our Heritage", was chosen to target the preservation of our heritage through conservation tillage and to recognize its interaction with integrated pest management. This year we are highlighting the entomological aspects of integrated pest management with six invited addresses in a mini-symposium titled "Insect Pest Management in Relation to Conservation Tillage". It seems appropriate to initiate the entomological aspects to conservation tillage in Florida because as our vice president for agricultural affairs would say, "we have less fertility and more insects in Florida than any other state in the Union". We suggest that for the next two years the conservation tillage meetings could be expanded to highlight weed-herbicide management practices and plant diseases.

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Importance of Designating Prevention and Suppression Control Strategies for Insect Pest Management Programs in Conservation Tillage

J.N. All[1]

Introduction

Insect pest management (IPM) is a broad concept and is considered from several perspectives by different entomologists. Most would agree that IPM programs usually involve more than one control tactic which are applied in a coordinated manner for the production of a commodity. All and Musick (1986) discussed IPM for conservation tillage systems as "the use of various preventive and suppressive tactics in as compatible a manner as possible while keeping the pest population at levels below those causing economic damage." The independent philosophies of prevention and supression of insect infestions are important in making IPM decisions for conservation tillage systems.

Preventive control utilizes habitat management, judicious crop or cultivar selection, sanitation or prophylactic insecticides to maintain insect populations at low levels. Preventive control involves two important concepts:

1. The realization that cultural procedures or crop cultivars can have either positive. negative. or neutral influences on crop/pest/pest natural enemy interactions: knowledge of all three effects is improtant in making IPM decisions. A cultural practice that has detrimental impact on insects is desirable in preventive programs and is termed **cultural control.** It is equally important to recognize practices that stimulate or have no effect on pest populations so that detrimental measures can he avoided and neutral ones utilized without fear of causing an outbreak.
2. The development and utilization of risk assessments or hazard ratings for specified cropping programs are fundamental for estimating the probability of developing insect infestations. Preventive control tactics usually have low economic risk and are normal agronomic procedures that do not increase the cost of producing the crop. Practices such as use of insect resistant or tolerant crops prcsume that seed cost and crop yield are compatible to other cultivars. Also, planting date selection, tillage practice. etc. must be cost effective for agronomic purposes as well as IPM. Insecticides are used in preventive control programs with the realization that there is a high probability of economic loss without them.

Due to the necessity to keep costs low, preventive control is often the predominant IPM strategy in conservation tillage systems. **Crop and cultivar selection** is the axis of many preventive control programs. The term **prohibitive crop selection** describes the selection of the least susceptible crop for a cropping program with specified pest hazards (All and Musick, 1986). For example, in double cropping conservation tillage systems where a field crop is planted following small grain harvest, use of soybeans often has an advantage over sorghum and corn due to lower relative susceptibility to several pests (Rogers, 1988).

The focus of **cultivar selection** is the use of pest resistant or tolerant varieties. Developing high yielding, agronomically acceptable crop cultivars with good insect resistance is difficult, time consuming work. Consequently, resistant cultivars are not yet available in many crops used in conservation tillage. In cases where insect resistant varieties are not available, IPM specialists should avoid commercial varieties that are highly susceptible and use the most tolerant cultivars available with other control tactics in an integrated program.

Crop rotation is a preventive control method that can he useful for certain insects which are categorized as resident pests. These insects have extended life cycles or restricted feeding behavior. Generally, when these pests establish infestations in a field, they will persist and often increase if the same crop is used year after year. Switching to a non-preferred host suppresses populations by disrupting the biologies or behaviors of resident pests. Crop rotation is not effective on insects categorized as transient pests due to the unpredictability of infestation from year to year. Additionally, these transient insects usually have multiple generations annually or have polyphagous or migratory hehavior and populations move readily among crops.

Habitat Management concerns the use of cultural practices to create enviornments that manipulate the interaction between the crop, insect(s), and insect natural enemies for IPM purposes. If the cropping enviornment has a nagative impact on pest populations, it is termed **cultural control** (Anonymous. 1969). Habitat management also recognizes the importance of cropping environments that have positive or neutral influences on pest populations in making risk assessments for IPM. An illustration is the **manipulation of planting date** for pest control which is based on knowledge of the phenological synchrony of a crop with damaging populations of resident or transient insects. Altering the planting date so that vulnerable crop growth stages do not coincide with peak insect populations is a centuries old IMP practice based on avoiding positive cropping enviornments for pests.

Conservation tillage and various types of **plow tillage**

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influence soil environments and have a major impact on the population potential of certain pests, and these influences may be positive or negative, depending on the insect. For instance, using no tillage enchances the risk of southern corn billbug, *Sphenophorus callosus* (Oliver), infestations in some areas (All el al., 1984), whereas, under other circumstances, losses from the lesser cornstalk borer, *Elasmopalpus lignosellus* (Zeller), are suppressed by conservation tillage (All el al., 1979).

Subsoiling, irrigation, fertilization and other cultural practices that stimulate optimum crop growth are habitat management practices that aid plant tolerance of insect injury. Since these practices often entail considerable cost, they are rarely adopted for the sole purpose of insect control. They are used as viable agronomic practices with the knowledge that they do not create environments that favor the biological potential of pests, and optimize growth of crops while under insect attack (All and Musick, 1986).

Biological control programs in conservation tillage involve habitat manipulation directed at **conservation** (avoiding cultural practices and pesticide use patterns that are detrimental to parasites, predators or pathogens of pests) or **enhancement** (producing cropping enviornments that maximize the biological potential of natural enemies) (Stehr, 1982). Surface debris from former crops in conservation tillage systems appears to benefit carabid beetles (insect predators) (House and All, 1981) and promotes maintenance of high numbers of Steinernemid nematodes (insect pathogens) near the soil surface (Hsiao and All, 1989).

To many agriculturists, **sanitation** is the disposal or destruction of plant debris and other refuse for hygienic purposes in crop fields. For entomologists, the term is narrowed to refer to measures that produce direct mortality to insects. Deep tillage can bury or destroy various life stages of insects residing in crop debris or in surface soil and has long been known as an effective sanitation technique (Anonymous, 1969). There is justifiable concern that lack of soil disturbance in conservation tillage systems provides sanctuary for resident populations of certain pests (All and Musick, 1986). Burning of crop refuse is a sanitation practice often used prior to conservation tillage operations. This procedure probably has some pest control value by killing insects on surface debris and by destroying food sources for pests. Burning has little value for control of subterranean insects because soil temperatures below a few centimeters do not increase more than a few degrees with a fast moving fire over agricultural land (J. N. All, 1989, unpublished data).

Insecticides are often used to protect crops and evidence indicates that they can be utilized effectively in Conservation tillage in a similar manner as plow tillage systems (All et al., 1979, 1984; All, 1988). Prophylactic insecticides are applied in situations where there is proven profitability from suppressing resident insects or when there is high risk of devastation from transient pests. The problems associated with reliance on preventive insecticides are numerous and well documented. Chemicals are expensive, insect populations commonly become resistant, and microbial degradation of certain insecticides may be increased in conservation tillage systems where chemicals are applied numerous times without soil disturbance (Felsot, 1987). Insecticides can be an important tool for conservation tillage IPM, but their use as a preventive control tactic must be mediated with awareness of their limitations.

Suppressive Control Measures

When insect outbreaks occur, preventive control measures do not act quickly enough to prevent economic loss. Application of insecticides by ground or air equipment is the primary tactic for suppressive control programs; research indicates that the methodology commonly used in plow tillage systems is equally effective in conservation tillage (All and Musick, 1986). Unlike many of the preventive control practices, chemical suppression of pest outbreaks has a singular purpose, to kill insects rapidly and efficiently. However, this tactic can be among the most expensive operations in producing the crop. Thus, the decision to deploy suppressive techniques is based on estimates of the magnitude of the pest population and the potential for yield loss without immediate control.

Action threshold (sometimes termed “economic thresholds”) have been established for many of the pests of field crops. These thresholds designate the point at which insecticides must be applied to prevent a current insect population from producing economic loss beyond the cost of chemical control. Insect populations are estimated by a variety of sampling techniques (e.g. crop “scouting,” insect attraction with pheromones or light traps, etc.) and correlations are made with yield loss. At the present time, few action thresholds are based on quantitative studies of the relationship between insect populations and yield loss (Pedigo, 1989).Most are more or less “educated estimates” made by entomologists experienced with insect management in different crops, and no thresholds have been developed for conservation tillage situations. Despite limitations, the use of action thresholds is invaluable in making chemical control decisions and it is probable that the thresholds available for crops in plow tillage systems are applicable to conservation tillage.

Concomitant Cropping Practices

IPM philosophy implies that preventive and suppressive control practices act synchronously to provide the most efficient management program for pest insects (All, 1987). With some modifications, IPM principles developed for crops in plow tillage systems are applicable for conservation tillage. Implementation of effectivepreventive control tactics should be the first priority when developing an IPM system for conservation tillage because these techniques are least expensive and are sound agronomic practices. However, surveillance of insect populations and utilizaion of action thresholds for decisions on suppressive control should be important components of IPM systems for conservation tillage (All, 1989).

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Soybean Insect Pest Management and Conservation Tillage: Options for the Grower

Dr. Ronald B. Hammond[1]

Introduction

The use of conservation tillage (CT) practices for soybean production has been relatively recent compared with corn. Development of effective post-emergent herbicides, development of better planters and drills, and the use of narrow rows to aid in weed control have all contributed to the adoption of conservation tilled soybeans. Conservation tillage has many effects on arthropods, both directly and indirectly (Hammond & Funderburk 1985, Hammond 1987). Often it is the direct effect of tillage practices on insect habitat, but more often it is the indirect effect through the presence of weeds or the impact of beneficial insects, both of which are more abundant in CT soybeans. This report will focus on how growers can have an influence on arthropod pests when CT impacts pest population dynamics. The two pests to be discussed in detail, seedcorn maggots (SCM), **Delia platura,** and slugs (a nun-insect pest of soybeans), are pests associated with CT in northern states. An overview of their relationship with CT will be followed by suggested grower practices that can reduce the negative impacts.

Selected Pests

Slugs: Slugs were one pest associated with CT practices a priori, that is, prior to the actually widespread adoption of CT. Indeed. they have become more of a problem in the eastern corn belt states as these practices were adopted. Studies by Hammond (1985) and Hammond & Stinner (1987) have addressed the relationship between slugs and CT. No only was the incidence of slugs highly correlated with the amount of residue left on the soil surface, but the previous crop also had a significant impact on slug populations. More slugs were obtained in no-tillage fields when soybeans were the previous crop compared with corn (Table l). No specific reasons were given for this difference, although the possibility of a more favorable habitat provided by legumes was suggested. Low slug densities were always found in the conventional tilled plots. The reports stated that the incidence of slug problems were likely to increase as CT practices became more accepted.

Of interest to this discussion is what growers can do to control slugs. Foremost is knowing that reduced tillage increases the potential for slug damage, while incorporating some of the crop residues will limit slugs' ability to cause economic damage. Obviously, this presents a problem for

Table 1. Average number of slugs per trap for interaction between tillage and previous crop in 1984 and 1985.

Previous Crop	Tillage: Conventional	Reduced	No-tillage
June 22, 1984			
Corn	0.0 d	0.5 cd	1.8 b
Soybean	0.0 d	0.7 c	3.5 a
May **31,** 1985			
Corn	0.3 c	0.8 c	1.6 bc
Soybean	0.1 c	3.6 b	8.8 a
June 14, 1985			
Corn	0.1 c	1.9 bc	3.6 b
Soybean	0.2 c	1.8 bc	11.3 a

From Hammond & Stinner (1987); Numbers within dates followed by different letter are significantly different according to Duncan's Multiple Range Test at the 5% level.

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strict no-tillage growers as they will usually be unwilling to employ any type of tillage. However, the grower willing to employ other CT practices (such as chisel plowing or light disking) which incorporate some of the residue can use that option to assist in keeping slug populations lower (keeping in mind CT by definition is any practice that allows 30% of residue to remain). A recommendation in the Midwestern USA for fields with a history of slug problems would be as follows: If early spring weather is cool and wet, and more of the same weather is forecast into June, incorporate some of the residue to aid in slug control. For those growers unwilling to use any tillage and for those who do but need additional control, they should be encouraged to keep a close watch on their fields, especially when following a legume. When a slug problem occurs, a molluscicide should be used. Although there is only one molluscicide available for controlling slugs in soybeans (a 24 State Label for Larvin applied as a bait), it does offer the grower an option.

Seedcorn Maggot: The association between SCM and CT soybeans bas been studied extensively in Ohio and Iowa for the past 8-10 years (Funderburk et al. 1983, Hammond 1984, Hammond & Stinner 1987, Higley & Hammond 1988, Higley & Pedigo 1984, and Hammond [unpublished data]). Funderburk et al. (1983) showed that no differences in SCM populations existed between in-row and between-row areas, suggesting that the soybean seed was not necessary for the insect to develop and perhaps served only as incidental feeding sites. This incidental feeding can cause economic losses if sufficient. Observations from Ohio (unpublished data) support this finding of high larval and pupal numbers in cultivated soils where no seeds were planted.

The Occurrence of SCM is more dependent on tillage practices and the incorporation of organic matter in the soil, with numbers of SCM varying depending upon the type of organic amendments. A three year study has been completed in Ohio which examined the interaction between tillage and cover crops/residues (unpublished data). Data from 1986 (Figure 1) illustrate results that were obtained during all 3 years. Few SCM adults were collected from no-tillage areas, supporting early studies that showed no-tillage practices do not increase SCM (Funderburk et al. 1983, Hammond 1984, Hammond & Stinner 1987). When organic matter is incorporated, SCM numbers increased dramatically with significant differences obtained between the type of organic amendments. More adults were collected from soils containing incorporated alfalfa, followed by rye, then soybean residue, and corn residue. Data analysis from all 3 years also indicated increased SCM numbers when legume covers/residues are incorporated compared with grass covers/residues.

Studies (Hammond 1984 and unpublished data) suggest that ovipositing female adults are attracted to the soils at the time of tillage, and the number of adults emerging from those soils are independent of the date of soybean planting. Growers who employ no-tillage practices should rarely experience problems with SCM. Those who use cover crops need to be aware of potential problems if those crops are incorporated. When growers opt to incorporate the cover by plowing, disking, or another form of tillage, they should be advised to treat their seed with an insecticide. Seed treatments are the

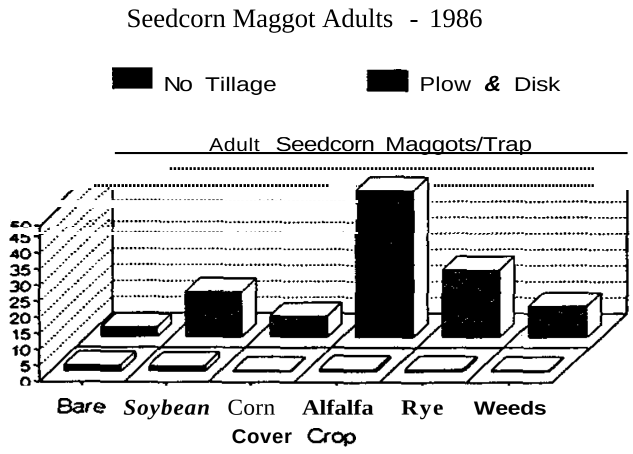

Figure 1. Average number of adult seedcorn maggots per trap in 1986.

most economical method of controlling the seedcorn maggot. Based on Ohio research, this recommendation is especially relevant when a legume is incorporated.

The alternative to using a seed treatment is to either delay tillage and planting until the adults in early May areno longer present, or to till early and then plant the soybeans during a period when the insect is in its pupal stage. Using the first of these options would require monitoring adults which would not be easy for most growers as special sampling techniques are necessary. The second option requires less effort by the grower. When the grower uses this option, not only do they plant when the insect is not feeding, but they plant when the soil is often warmer which would allow for more rapid seed germination. Population dynamics studies suggest that adults emerge after approximately 400 heat units have accumulated following oviposition (Hammond 1984). The insect enters the pupal stage at approximately 234 heat units following oviposition (Sanborn et al. 1982). Assuming that most eggs are laid within a few days of tillage, the majority of the population would be in the same stage throughout its life cycle. Over the past 5-6 years of sampling for SCM, the majority of adults emerge from the soil in late May or early June within days of each other. The recommendation for growers who do incorporate a cover crop in early May is to delay planting soybeans until approximately 234 heat units have accumulated from the time of tillage (see Figure 2). The

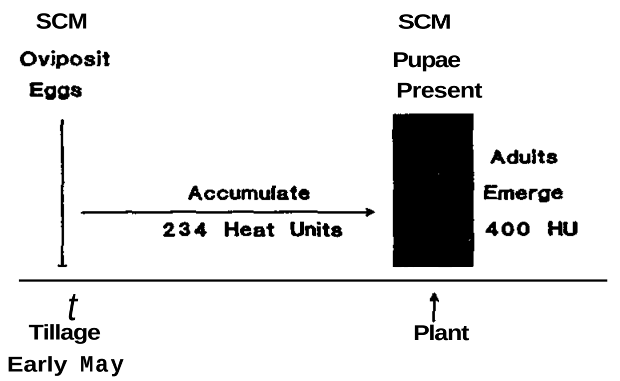

Figure 2. Hypothetical tillage and planting date system for escaping seedcorn maggot damage.

majority of SCM should be in the pupal stage, and the damage potential to germinating soybeans will be minimized.

Adult fly emergence based on time of tillage rather than planting is supported by a second study done in Ohio (unpublished data) where the interaction between planting date and use of various soil insecticides was studied. Soybeans were planted at varying times into soil that had a rye cover crop incorporated in early May (within 24 h of tillage, 1.5 wk later, and 3 wk later). In 1987, the control plots (without any insecticide treatments) which were planted 1.5 week after tillage had equal numbers of emerging SCM flies (21.3 SCM adults per trap) compared with plots planted within 24 h of tillage (21.1 SCM adults per trap). Control plots planted 3 weeks following tillage, although having significantly fewer SCM adults emerge (16.6 SCM adults per trap), nonetheless had a noticeable population. The majority of the adults in the control plots from all three plantings emerged within a 6 day span, with the percentage of adult emergence on each collection date being nearly equal. The percentage of the total number of adults collected per planting date for the first three collection dates were as follows: 1st collection date = 56%, 54% and 41%. 2nd collection date = 18%. 15%, and 20%, and 3rd collection date = 22%, 24% and 27% for the three planting dates, respectively. This is a good indication that oviposition occurred over a relatively small time period, since SCM adults emerged equally from plots planted over a 3 week period. The percentage of plants damaged by the seedcorn maggot decreased with each planting date (1st planting date = 19.6%, 2nd planting date = 8.1%, and 3rd planting date = 6.8%). While the first planting date immediately after tillage had high numbers of SCM and a high percentage of damaged plants, the percentage of damaged plants from the second planting date were significantly less although the number of SCM was equal.

Discussion

Although this report has dealt with situations in the niidwestern USA, its ideas also pertain to the southern USA. Conservation tillage in the southern USA involves numerous agronomically acceptable tillage and subsoiling practices, and as in the midwestem USA, the interactions between various pests and these practices have been studied. Lesser cornstalk borer damage in CT is often greater when weeds and crop residues are burned prior to planting due to soybeans being the only available food source. *Heliothis zea* populations are reduced in CT fields due to the destructive effects of plowing and disking on pupal mortality. Velvetbean caterpillar numbers are lower in weedy soybeans (often associated with CT) due to the greater predator populations and reduced soybean biomass in weedy soybeans. All these relationships offer options such as weed and crop residue burning, light tillage and companion cropping that growers can use to reduce pest populations.

What does the future hold in store? We will see more work on the impact of weeds and companion crops in CT soybeans, not only in terms of yield but also on the interactive effects on pest arthropod populations. We already know of specific situations where grasses can have a significant impact on soybean pests. Both wheat and grassy weeds lowered populations of potato leafhoppers in soybeans in various soybean production systems in studies conducted in Ohio. Perhaps we will develop options that uses such companion plants to lower certain pests to manageable levels.

The area of research having the greatest potential is with beneficial insects which are more diverse and numerous in CT fields. As the biocontrol potential of beneficial insects is better understood, the option of modifying tillage practices to allow for increased predator and parasite activity might be developed. This work is already being explored. Funderburk et al. (1988) recently published work showing higher numbers of bigeyed bugs and damsel bugs, two important predators in the South, in disk tilled soybeans compared with no-tillage systems. The day will come when grower recommendations on the type of tillage to use is done to allow for greater biocontrol of insect pests.

As Herzog & Funderburk (1986) concluded, each crop and pest situation must be evaluated individually and control decisions made for each specific geographic location. The first step is determining the effects of specific tillage practices on both pest and beneficial insects. When those are known, a conscious effort should be made to develop useable options for the grower. Sometimes that option might not be exactly what the grower will want to hear. However, it may not be so far removed as to make it completely unusable. Those are the options that need exploring.

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Insect Pest Management and Conservation Tillage of Soybean Doublecropped with Winter Wheat

J.E. Funderburk[1], D.L. Wright, and I.D. Teare.

Introduction

Reduced tillage was rapidly adopted in the 1970's and 1980's to reduce soil erosion and the costs of production. Although tillage operations modify the soil habitat where many pests spend at least part of their life cycles, impacts of reduced tillage practices on crop losses from pests were not initially evaluated. Soil turning and residue-burying practices generally were believed to negatively affect most pests, thereby leading Gregory and Musick (1976) to speculate that reduced tillage practices increased crop losses to pests.

Considerable research now has been conducted on insect pests in reduced tillage crop-production systems. Hammond (1986) and Hammond and Funderburk (1985) reviewed the numerous studies involving soybean [Glycine max (L.) Merr.]. Most soybean pests and their natural enemies whose populations have been quantified in tillage studies are affected to at least some extent by tillage practices, but crop losses can be either increased or decreased. These findings led Herzog and Funderburk (1986) to conclude that each pest situation must be evaluated individually and control decisions made for each specific geographical location.

Conservation tillage is employed in the southern USA to produce soybean double cropped with winter wheat [Triticum aestivum (L.)]. Conservation tillage practices include disk tillage and no tillage. In the Coastal Plain of this region, subsoiling combined with reduced tillage frequently is used. Although arthropod pests are a major management consideration in integrated pest management programs in this region, the effects of tillage and subsoiling on population dynamics of pests and their natural enemies are not known.

Most economic losses from soybean arthropod pests in the southern USA result form injury to leaf blades and fruit. The major defoliating pest is the velvetbean caterpillar (VBC) *(Anticarsia gemmatalis* Hubner), but the soybean looper (SBL) *[Pseudoplusia includens* (Walker)] and the green cloverworn (GCW) *[Plathypena scraba* (Fahricius)] also sometimes reach economically important densities. The major pests of fruit are podworms *(Heliothis* spp.) and the stink bug complex. The southern green stink bug (SGSB) */Nezara viridula* (L.)] is the predominate stink bug pest species.

Soybean fields are inhabited by a complex of indigenous natural enemy species. Pitre (1983) and Shepard and Herzog (1985) review and discuss the published information available on natural enemies in soybean. The available research has demonstrated that the indigenous natural enemy complex is vitally important in reducing pest levels. The combined activity of the natural enemies prevents many pest species from reaching economically damaging levels and reduces the seventy of outbreaks of other pest species. Integrated pest management programs of soybean are designed to optimize the benefits from indigenous natural enemies.

Studies were conducted to evaluate the effects of tillage and subsoiling on population dynamics (population densities and population cycles) of major pests and insect predators in soybean doublecropped with winter wheat. Pests were VBC, GCW, and SGSB, and insect predators were bigeyed bugs (Heteroptera: Lygaeidae) and damsel bugs (Heteroptera: Nabidae). Both bigeyed hugs and damsel bugs in soybean in the southern USA consist of a guild of several closely related species (Funderburk and Mack, 1987, 1988).

Materials and Methods

Soybean were grown on a Norfolk sandy loam soil (fine-loamy siliceous, thermal Typic Paleudult) at Quincy, FL. Treatments were (1) disk (gang disk in two directions, 0.15 m depth) and plant; (2) disk, subsoil (chisel plow at a depth of 0.23 m) and plant; (3) no till and plant; and (4) no till, subsoil, and plant. A 2-row cone planter was used to plant the soybean at 25 mm soil depth in all plots. In 1985, 'Cobb' soybean were planted on 30 July in plots 7.6 x 30.4 m in size. In 1986, the cultivar was changed to 'Kirby' soybean which was planted 11 June in plots 7.6 x 24.4 m in size. The soybean planting rate was 45 kg ha' both years. No irrigation was needed or applied to the plots in 1985, but in 1986 25 mm water ha^{-1} was applied preplant and at intervals during the growing season when tensiometers reached 0.02 MPa. Herbicide applications in each treatment each year are given in Funderburk et al. (1988).

Densities of GCW, VBC, SGSB, bigeyed bugs, and damsel bugs were estimated on 6 dates during 1985 (8-23, 9-4, 9-16, 9-28, 10-9, 11-6) and on 5 dates in 1986 (7-3, 7-15, 7-29, 8-12, 8-28). The sixth sampling date was discontinued in 1986 because of excessive lodging caused by heavy rains and high winds. Sampling was begun at early vegetative stage (V4) in both years and continued to the late pod fill stage (R7) of crop growth in 1985 and the middle podding state (R4) in 1986. Insect sampling was carried out as described by Kogan and Pitre (1980). All plots were sampled on each sample date by beating the plants on both sides of the row into a 0.9 m square ground cloth placed between the rows. Three samples were taken per plot on each sample date. Also, adjacent plant bases and the soil surface were visually examined.

The influence of preplant tillage treatment on population densities and population cycles of VBC larvae, GCW larvae, SGSB adults, SGSB nymphs, damsel bug adults and nymphs, and bigeyed bug adults and nymphs were evaluated by ANOVA. Data from each growing season were analyzed separately. The design was a split plot in time (Steel and Tome, 1960). The main effect of tillage treatment compared the influence of preplant tillage treatment on seasonal densi-

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ty. Orthogonal comparisons were used to define treatment differences. The interaction of date*treatment compared the influence of preplant tillage treatment on seasonal population cycles. Conservative degrees of freedom were used in each ANOVA, since the effect of date could not be randomized.

Results and Discussion

Seasonal population dynamics (population density and population cycles) of larval VBC, larval GCW, and nymphal SGSB are shown in Figure 1. Density estimates of VBC

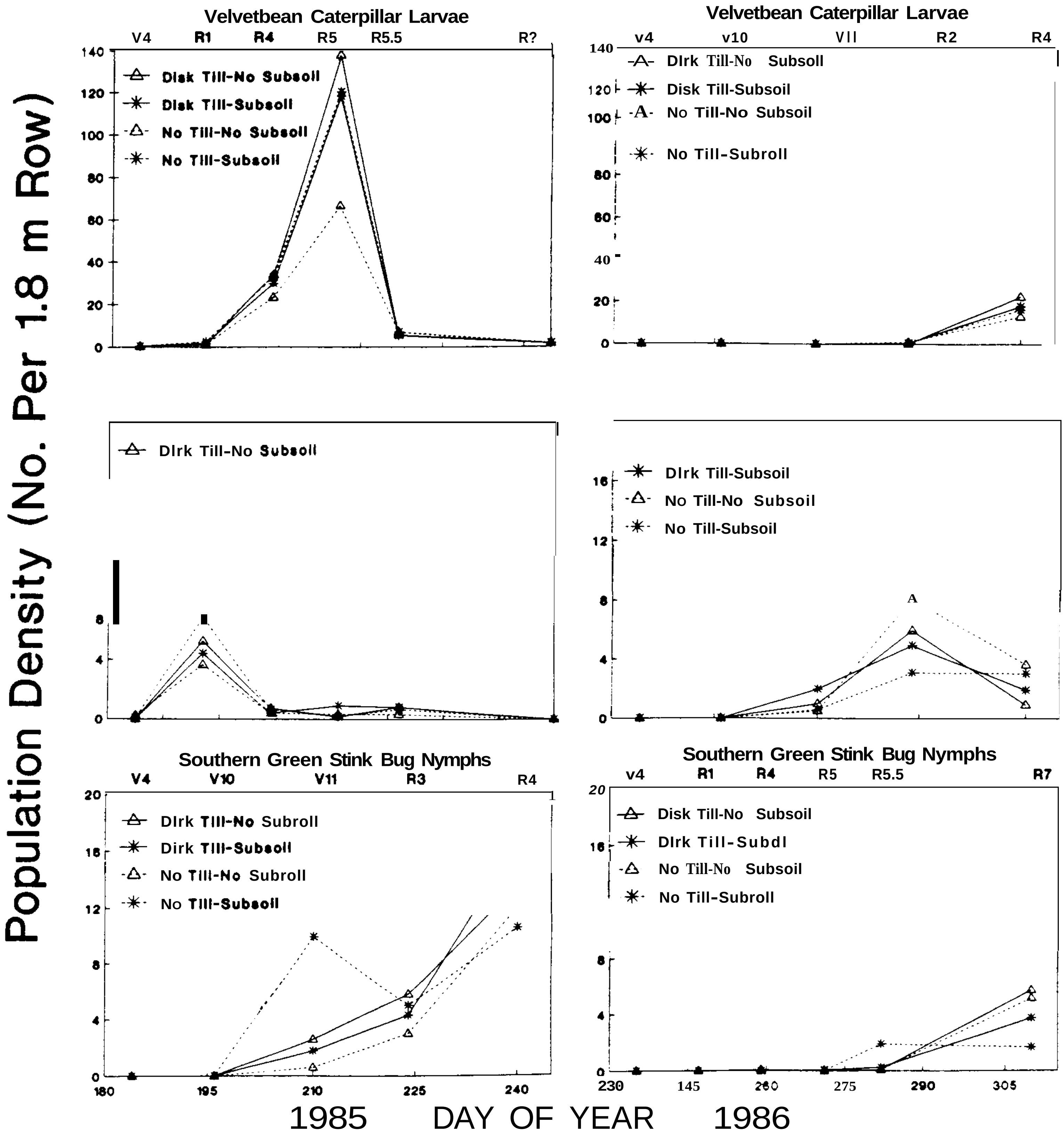

Figure 2. Density of nymphal bigeyed bugs and damsel bugs in preplant tillage treatments in relation to day of year (Days Julian, 1985 and 1986) and physiological stage of soybean development.

sometimes exceed economic thresholds (12 larvae per meter or row) when control procedures are recommended in production fields (Johnson et al. 1988). VBC estimates in all treatments were > the economic threshold density on sample dates during soybean growth stages R4 and R5 in 1985. Population densities of VBC were not economically important on any date in 1986, probably because sampling was discontinued at R4 for the remainder of the season due to lodging. GCW population estimates in all treatments were below economic threshold levels (same as VBC) on all sample dates in 1985 and 1986. The shake cloth sampling procedure resulted in poor precision for estimating density of adult SGSB; therefore, adult sample estimates are not given in Figure 1. SGSB estimates exceeded the economic threshold (Johnson et al., 1988) during R7 in 1985 and R2 and R4 in 1986.

Preplant tillage practices had little effect on population densities or population cycles of VBC, GCW, or SGSB. Population densities of VBC differed between preplant tillagetreatmentsin 1985 ($F = 14.1$; df $= 1,18$; $P < 0.0001$). Orthogonal treatment comparisons showed that density was significantly less in the no till without subsoiling treatment than in the other three treatments ($F = 13.5$; df $= 1, 18$; $P < 0.001$). Other orthogonal comparisons were not significantly different ($F = 2.7$; df $= 1, 18$; $P > 0.05$). Populationcycles differed between preplant tillage treatments in 1985 ($F = 10.5$; df $= 5, 18$; $P < 0.0001$), because estimates were similar on sample dates when densities were very low and not similar on other sample dates when densities were greater. Significant effects on population dynamics of VBC in 1985 may relate to the very late planting of the soybeans that year, because plant growth was visibly retarded in the no till without subsoiling plots. The density of VBC was similar in all preplant tillage treatments in 1986 ($F = 0.6$; df $= 1, 15$; > 0.05). Population cycles also were similar in 1986 ($F = 0.8$; df $= 4, 15$; $P > 0.05$).

GCW population densities were similiar in all preplant tillage treatments in 1985 and 1986 ($F = 0.9$ and 0.2, respectively; df $= 1, 18$ and 1, 15, respectively; $P > 0.05$). Likewise, population cycles were not affected in 1985 and 1986 ($F = 1.5$ and 1.8; respectively; df $= 5, 18$ and 4, 15, respectively; $P > 0.05$). Population densities of nymphal SGSB were statistically similar in each preplant tillage treatment in 1985 and 1986 ($F = 0.2$ and 0.3, respectively; df =

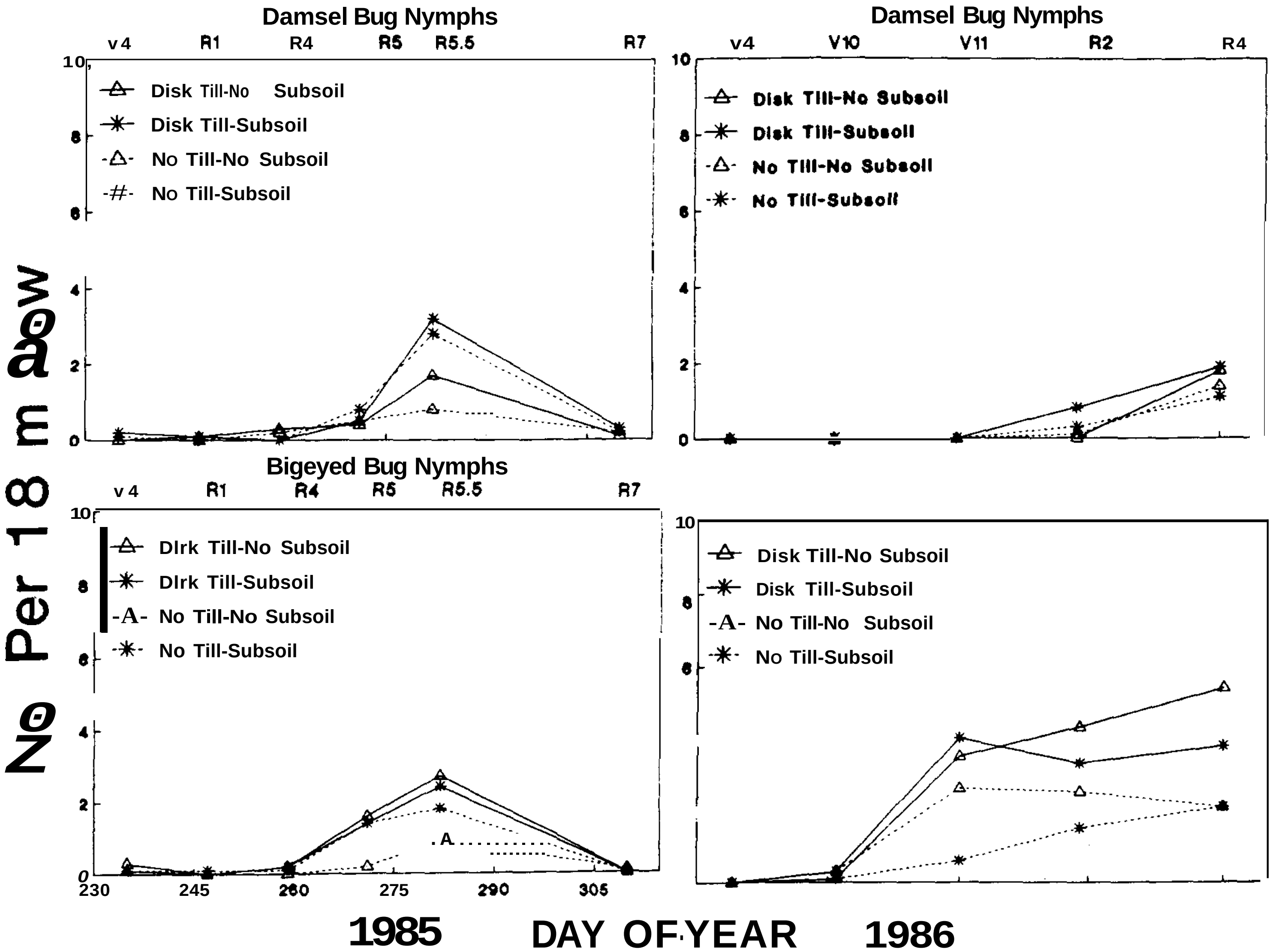

Figure 1. Population density of larval velvetbean caterpillar, larval green cloverworm, and nymphal southern green stink bug in preplant tillage treatments in relation to day of year (Days Julian, 1985 and 1986) and physiological stage of soybean development.

1,18 and 1,15, respectively; $P > 0.05$). Population cycles were not affected in 1985 and 1986 ($F = 0.9$ and 0.7, respectively; df = 5.18 and 4.15, respectively; P 7 0.05). Another experiment was conducted by Funderburk et al. (1989) to evaluate influences of preplant tillage practices on population dynamics of VBC, GCW, and SGSB. Population densities and population cycles of these pests were not significantly affected in this experiment.

Population dynamics of the insect predators were affected by preplant tillage treatments, but only data for nymphal sample estimates are presented (Fig. 2). Densities of nymphal bigeyed bugs were significantly affected by preplant tillage treatments in 1985 and 1986 ($F = 3.9$ and 6.7, respectively; df = 1,18 and 1.15. respectively; P is < 0.05 and 0.01, respectively). The orthogonal treatment comparisons revealed that treatment differences were due to tillage practice. The harrowed with subsoiling and harrowed without subsoiling treatments had greater bigeyed but numbers that the no till with subsoiling and no till without subsoiling treatments in 1985 and 1986 ($F = 7.3$ and 17.2, respectively; df = 1.18 and I, 15, respectively; P is < 0.05 and 0.01. respectively). Other orthogonal comparisons were not significantly different in 1985 or 1986 ($F = 1.2$ and 2.6, respectively; df = 1,18 and 1,15, respectively; P is > 0.05). Population cycles of nymphal bigeyed bugs were not affected by preplant tillage treatment in 1985 and 1986 ($F = 1.4$ and I .6, respectively; df = 5,18 and 4, 15, respectively; P is > 0.05).

Densities of nymphal damsel bugs were statistically similar in each preplant tillage treatment in 1985 and 1986 ($F = 2.0$ and 0.3, respectively; df = 1,18 and I,15, respectively; P is > 0.05), but densities were numerically lowest in the no till without subsoiling plots (Fig. 2). This difference was significant for adults (data for adults are reported in Funderburk et al. (1988)). Population cycles of nymphal damsel bugs were not affected by preplant tillage treatments in 1985 or 1986 ($F = 1.8$ and 0.8, respectively; df = 5,18 and 4,15, respectively; F is > 0.05).

Our findings provide important information for integrated pest management programs of soybean doublecropped with winter small grains in the Coastal Plain of the southern USA. (I) Preplant tillage practices have little gross effect on the population dynamics of VBC, GCW, and SGSB. (2) Bigeyed bugs and damsel bugs are increased by the selection of disk till rather than no till. Although not greatly affecting the amount of pest stress, preplant tillage practices should be a consideration in soybean integrated pest management programs. Biological control is a desirable control tactic, and integrated pest management programs are designed to optimize the benefits of biological control. The amount of predation of soybean insect pests is a function of predator population density (O'Neil, 1984); therefore, enhanced predator populations may reduce outbreaks from pests other than VBC, GCW, and SGSB. Additionally, it may be possible to combine other production modifications (e.g., resistant cultivars) with preplant tillage practices to achieve reduced pest injury.

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Direct and Indirect Effects of Conservation Tillage on the Management of Insect Pests of Cotton

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Introduction

Conservation tillage systems take many different forms. Systems proposed for cotton *(Gossypium hirsutum L.)* have ranged from winter-fallow with various types of reduced spring-tillage (including no spring-tillage) to double-crop systems using small grains, vetch *(Viciusaiiva L.)* or reseeding crimson clover *(Trifolium incarnutum L.)* as the winter-cover. Cover crops have been managed in a variety of ways, including I) planting directly into the growingcover crop, 2) using chemicals to hasten maturity or to kill the cover crop. and 3) waiting for the cover crop to mature before planting cotton. Although adoption of any of these systems is patentially beneficial, any of the systems also may cause unexpected consequences for management of pests of the crop. These consequences may be caused by direct or indirect effects of the system on insect populations in individual fields, or they may be caused by indirect effects acting on insect populations over the entire agroecosystem.

Results and Discussion

Direct Intrafield Effects

Since most insect pests of cotton attack the above-ground portion of plants, direct effects of soil tillage practices usually have been minor and relatively easy to determine. Normal tillage operations cause significant mortality to *Heliothis* spp. pupae (Fife and Graham, 1966; Hopkins et al., 1972; Roach, 1981a). Mortality was attributed to mechanical damage to larvae and to destruction of burrows. Reduced tillage would reduce mortality to pupae present in the soil when tillage occurred.

Tillage operations modify soil texture, temperature, and moisture, and may affect the behavior and survival of *Helioihis* entering the soil after tillage occurs. Prior to pupating, *Helioihis* prepupae moved further on smooth, compacted soil than on rough, soft soil (Roach and Hopkins, 1979). Fewer adults emerged from the compacted soil (Roach and Campbell, 1983).

Ultimately, in most years increased or decreased *Helioihis* survival within an individual field may be inconsequential because of the mobility of adult *Helioihis* spp. (Raulston et al., 1982). In some agroecosystems economically damaging *Helioihis zea* populations in cotton migrate to cotton from mature field corn *(Zea mays L.)* rather than increasing within the cotton field Landis et al., 1987). In other ecosystems, *Heliothis virescens* populations are thought to build within cotton fields in the same local area.

In South Carolina, in one year of a three-year study. *Helioihis* populations and damage were significantly lower in conservation tillage plots with no winter cover than in conventional tillage plots (Roach, 1981b), but no reasons for this difference were determined. There were no differences in *Heliothis* numbers or damage the other two years. In Alabama, *Heliothis* populations and damage to cotton did not differ among four cover crop treatments (conservation tillage) and a conventional tillage control except on one date in the two-year study. In late-July, 1981 cotton following clover received less damage to squares (4.2%) than cotton in the other plots (20.2%), but this difference was attributed to the stressed condition of cotton following clover causing this cotton to be less attractive to ovipositing moths (Gaylor et al., 1984). Thus, tillage systems have not been found to markedly impact *Heliothis* populations or damage within the same field.

One group of insects that is a potentially greater pest in conservation tillage cotton is the cutworms. In other crops (e. g., corn) cutworms are typically more damaging in conservation tillage fields (Harrison et al., 1980). These insects occur in damaging numbers only sporatically in cotton, hut seem to infest cotton fields with a heavy mulch in greater numbers than cotton with a clean soil surface. Significantly greater numbers of varigated cutworms Peridroma saucia (Hubner) were found in cotton with a heavy clover mulch than in cotton following hairy vetch *(Vicia villosa* Roth). No cutworms were found in cotton produced conventionally or in conservation tillage systems with no winter cover or a rye *(Secale cereale L.)* mulch (Gaylor et al., 1984). In contrast, Roach (198Ib) found no significant difference in black cutworm *Agrotis ipsilon* (Hufnagel) populations or damage in conventional and conservation tillage plots, but their conservation tillage plots had no winter cover.

Indirect Intrafield Effects

One way a tillage system might indirectly impact pest populations is through effects on predators or parasitoids. Predator populations in the herbaceous strata of cotton were not affected by tillage systems (Gaylor and Foster, 1987; Roach, 1981b). However, reduced tillage led to increased numbers of ground-dwelling predators, which decreased survival of *Heliothis* prepupae and pupae in cotton (Gaylor and Foster, 1987). Landis et al. (1987) found that *Helioihis zea* pupal survival in corn was not affected by previous tillage, but they suggested that their cages may have restricted movement of predators and parasites, and may have reduced *Helioihis* survival. A more important indirect effect occurs if reduced tillage systems delay planting or maturity of the crop. Conservation tillage systems which leave a mulch on the soil surface resulted in cooler soil temperatures than in hare soil (Grisso et al., 1984). Cool soil temperatures result in poor seedling growth and a greater incidence of seedling disease (Rickerl et al., 1988). Waiting until mulched soils have warmed to ideal temperatures results in delayed planting, and consequently, in delayed maturity. Even greater delays in maturity occur if cotton planting is delayed to allow the cover crop to mature. These delays

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occur in conservation tillage systems designed to take advantage of the ability of a winter cover to reseed itself (e.g., crimson clover or vetch) (Touchton et al., 1984) or to harvest the winter cover in a double-crop system. In double-crop systems, cotton planting may be delayed for over 1.5 months (Baker, 1987). This much delay in maturity is contrary to the aims of most insect management systems (Adkisson et al., 1982) and has the potential of causing substantial late-season damage by boll weevil *(Anthonomus grandis Bohman)* and *Heliothis* spp. Other problems associated with a late-harvest are also economically damaging (Parvin and Smith, 1986).

In one study, however, boll weevil damage was substantially lower in cotton double-cropped with wheat *(Triticum aestivum* L.) than in cotton planted conventionally. The fields planted first (conventionally), in the mosaic of conventional and double-crop fields present in the area, acted as effective trap-crops for boll weevils (Gaylor and Foster, 1987). *Heliothis* spp. populations and damage were not significantly different between the early- and late-planted cotton. However, *Heliothis* populations were very low during both years of this study. The late-planted cotton produced fruit later than the conventional cotton, and thus, was vulnerable to insect attack later than conventionally-planted cotton. Also, the later planting made the double-crop cotton more susceptible to the drought that severely reduced yields in 1984. Irrigation and the development of varieties of cotton and cover crops that mature more rapidly may make double-cropping more feasible in the future (Baker, 1987; Roach and Culp, 1984), but effects of these modifications of double-crop systems on pest damage have not been determined.

Indirect Ecosystem Effects

Agroecosystem-wide effects of conservation tillage systems on pest populations and damage to cotton are difficult to determine, but these effects may be extremely important. In many ecosystems intensively managed for agriculture, because of high winter mortality and because spring hosts occupy a small portion of the total acreage, *Heliothis* spp. often do not cause economic damage to cotton until the third generation is produced in July. There have been no studies to determine effects on *Heliothis* populations in cotton of substantially increasing early spring host populations. This increase would occur if substantial acreage of cotton was produced in a conservation tillage system utilizing clover or vetch as winter cover crops. However, studies on the effects of reducing these host populations may allow inferences to be drawn about ecosystem-wide effects of utilizing conservation tillage systems that include cover crops that are good *Heliothis* hosts.

Crimson clover and hairy vetch are legumes which potentially could provide much of the nitrogen required for cotton production, and if allowed to mature, would not have to be replanted annually (Touchton et al., 1984). However, these hosts were among those supporting the largest populations of *Heliothis* in early spring (Stadelbacher et al., 1984; Harris and Phillips, 1986). Mueller and Phillips (1983) found over 100,000 *Heliothis* per acre during the spring on crimson clover. Fortunately, under present production systems, only a small portion of the total rural land acreage presently supports early spring hosts of *Heliothis.* In the Delta of Mississippi, only ca. 3.5% of the rural acreage supports weed hosts of first generation *Heliothis* spp. (Stadelbacher, 1982). A reduction of only 50% in the *Heliothis* larval population (by mowing weeds), in an area with only 3.5% of the acreage supporting *Heliothis* hosts, reduced the damage to cotton to below that in an unmowed control area (Harris and Phillips, 1986). If only one third of the ca. 1 million acres of cotton in the Mississippi Delta were produced with a winter cover of clover, the acreage of early-spring hosts would double. Assuming no increased mortality due to density dependent mortality factors, the *Heliothis* spp. produced probably would cause economic damage to cotton much earlier in the season than at present. Thus, insecticide applications would begin earlier in the season.

Summary

Effects of modified tillage systems on insect populations and damage to cotton are still unpredictable and may be site specific. For example, in an area where damaging *Heliothis* spp. populations immigrate to cotton from alternative crops, conservation-tillage may have little impact on damage. In an area where *Heliothis* populations build within cotton fields, reduced pupal mortality from reduced tillage may be important. Because of the mobility of insects, effects of modified tillage systems may extend far beyond field boundaries. These effects will be difficult to determine experimentally, but may profoundly influence the profitability of the agricultural enterprise. Thus. it is essential that agricultural scientists take a holistic approach to production research.

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Effect of Non-crop Vegetation on Insect Infestations and IPM in Reduced-Tillage Corn and Sorghum Production Systems in Low and High Technology Agriculture

H. N.Pitre* and R.P. Porter[1]

Abstract

Nan-crop vegetation in conservation tillage systems can influence the abundance and importance of phytophagous insects and plant diseases in contrasting ways in low and high technology agriculture. In Honduras, non-crop vegetation in fields of interplanted corn and sorghum may either increase or reduce damage to the crops by insect pests, depending on larval host food preferences, and the timing and efficacy of weed removal procedures. A complex of four lepidopterous species attacks broad leaf weeds and grasses in subsistence production fields prior to crop planting. The larvae move from this vegetation onto the seedling corn and sorghum and damage or destroy the crops. Weed removal from production fields is recommended to lower insect pest abundance and reduce damage to the crops. Corn production in the high input crop production systems in the southeastern United States can heused to illustrate the divergent roles of weeds in influencing insect vector abundance and incidence of two insect-borne diseases, namely maize dwarf mosaic and corn stunt. Johnsongrass, an early season host for maize dwarf mosaic virus and host for aphid vectors, is responsible, in part, for aphid population buildup during early spring and is a source of innoculum to the aphid vectors, particularly the corn leaf aphid. Removal of Johnsongrass would eliminate this host for aphids and the maize dwarf mosaic virus. Conversely, the incidence of corn stunt disease may he correlated directly with amounts of non-crop vegetation in production fields. Conservation tillage methods may help reduce losses to corn stunt disease by allowing weeds to develop in the field. The black faced leafhopper vectors prefer to feed on the non-crop grasses and remain on these weeds, feed less on corn and thus the incidence of corn stunt disease is lower in the field. Weedy corn fields have the highest number of leafhopper vectors, hut a lower incidence of corn stunt disease than weed-free fields.

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Introduction

Eighty-two percent of the world's population is found in developing countries. These countries occupy 62% of the world's land area. The needs of agriculture in developing nations can differ greatly when compared with developed nations, and the solutions to many of the agricultural problems in the former, must of necessity, be different from those of the latter (Mellor, 1988).In developed nations, agricultural production relies heavily on inputs of fuel, fertilizer, insecticides, fungicides, nematicides, and herbicides. Crop varieties are developed and chosen for optimal yield under these high-input conditions. Agriculture in developing nations has evolved differently, and remains more vulnerable to climatic and pest uncertainties. Here, human and animal power have not been replaced by fossil fuels (Oram, 1988). and agricultural chemicals are not in common use.

A major goal of high technology, mechanized agriculture is to optimize return on investment, or stated another way, the goal is to derive the maximum dollar return per dollar spent on production. The farmer's profit depends upon inputs, yield, and the value of his crop at the time of harvest or some future date after storage. Laws of supply and demand, global grain supplies, and governmental programs influence directly the value of the high technology farmer's commodity. The low technology farmer in a developing nation often faces different circumstances. His crop will usually be consumed on farm, and a portion may be sold for capital. Choice of crop and cropping practice is often determined by local needs and/or weather patterns (DeWalt and DeWalt 1984) and crops are often interplanted in order to minimize risk of total crop loss.

By addressing some aspects of corn (or corn/sorghum) production we will illustrate the divergent role of weeds in influencing insect abundance and associated feeding damage and/or incidence of plant diseases in low technology and high technology agricultural systems.

Low Technology Corn Production

Corn and sorghum are often grown intercropped together in low technology, subsistence farming systems in many areas of Latin America. In years of high corn yields, corn is used for human consumption and sorghum is often fed to livestock (Hawkins, 1982). In years of severe drought, corn often fails and sorghum is then used for human consumption.

In Honduras, a complex of lepidopterous species attacks corn and sorghum during both the first (primera) and second (postrera) growing seasons. These pests are collectively referred to as the "langosta" (Pitre, 1989). and they frequently destroy crop stands in the first plantings. The most damaging members of the langosta during the early growing season are the fall armyworm (FAW), *Spodoptera frugiperdu* (J. E. Smith), the southern armyworm, *S. eridania* (CRAMER), and *Metuponpneumata regenhoferi* Moschler. The grasslooper, *Mocis latipes* (Guenee), reaches pest status Some years.

The presence of non-crop vegetation near or within fields may either promote or reduce pest damage, depending on the pest and plant species involved, and the duration of feeding and extent of damage caused by the insects to the non-crop host plants (Pitre, 1989;Portillo, 1989 personal communication). Moths oviposit on non-crop vegetation and larvae move onto the crop after they have consumed the weeds. Broad leaf plants are more common than species in the Graminae. The lepidopterous larvae feed on seedlings and young whorl stage plants of the broad leaf weeds, including *Melumpodium divaricatum* (L.C. Rich) and *Portulaca aleraceu*, L. and grasses, including *Seraria* sp.. *Echinodea sp.*, *Cynodon dactylon*, (L.) *Ixophorus unisetus* (Presl) Schlecht., *Punicum* sp. and other unidentified species. At least nine broad leaf weeds and six grass species (not all identified) were present in our study fields in southern Honduras (Pitre, unpublished). Knowledge of the biological and ecological relationships between the insect pests and non-crop vegetation in and around production fields is useful in developing cultural, non-chemical insect pest management practices. Pitre (1989) recommended the removal of non-crop vegetation from fields and field borders as a means of reducing larval numbers and damage to the corn and sorghum crops in the primera.

Of the many pests of corn and sorghum in Honduras, the FAW is one of the most serious. In southern Honduras, it is the major constraint to successful corn and sorghum production (DeWalt and DeWalt, 1984). Castroet al. (1989) found that FAW infestations were lowest in sorghum fields with a natural weed complex present compared with sorghum monoculture or sorghum intercropped with corn. Similarly, Altieri (1980) found that weed-free corn fields in monoculture in Florida had twice as many FAW larvae as weedy corn fields. His studies in Colombia also showed fewer FAW larvae in corn fields with weeds, compared with fields with good weed control. Castro et al. (1989) speculated that crops in weedy fields were stressed through competition with weeds, and hence were nutritionally less fit for the FAW than crops in other treatments. This is based on the fact that FAW lays more eggs on sorghum grown with adequate fertilization than sorghum grown under suboptimal nutrient conditions (Van Huis, 1981). Additionally, weedy corn or sorghum fields have fewer FAW larvae than fields with fewer weeds because the weeds may reduce the moths' host finding ability (Altieri and Whitcomb, 1980). Root (1973) proposed the "resource concentration hypothesis" for situations in which non-crop species associated with preferred crop species reduce the ability of a herbivore to detect and utilize its host plant. Such reduced responses by herbivores may result through masking cues that potential herbivores use to detect appropriate hosts, or may be due to a subtle alteration in the microclimate so as to encourage a pest's emigration from the field (Risch et al. 1983). An alternative hypothesis, the "natural enemies hypothesis" was proposed by Pimentel (1961). According to his hypothesis, increases in pest mortality are observed in more diverse fields. Consequently, fields with higher diversity and increased stability have more abundant natural enemies than fields with less diverse vegetation. There is obviously a practical limit to beneficial weediness in a field, and Risch et al. (1983) suggest that this point is reached when the positive effects of diversity are out-weighed by the loss in yield due to plant competition.

High Technology Corn Production

The high technology producer has a different set of tools with which to address a different set of problems. Subsistence farming is not his goal, rather, it is to maximize return on investment. Where the major risks faced by the low technology farmer may be weather and pests in producing enough food on a small amount of land to feed his family, the high technology farmer is more concerned with weather, commodity prices and the interest rate at his local bank.

One method of cost control in agriculture is the adoption of conservation (= minimum = reduced) or no-tillage crop production techniques. In general, conservation tillage reduces producer costs and soil erosion, preserves soil moisture, and may influence pest biology and behavior through reduced soil temperatures and altered vegetational structure within fields. This practice has been addressed in a recent review by Pitre and Porter (1989). Reduced tillage methods have become widely accepted in the U.S., but pest problems constitute a serious limitation to acceptance of these techniques in reduced-input agriculture.

While increased weed abundance in no-till fields can cause direct yield loss through weed/crop competition, this may not always be the major factor in yield reduction. Insects associated with crop and non-crop vegetation may transmit plant disease agents from plant to plant, and their role as vectors is usually more important than their direct feeding injury (Knoke, 1976). Two vector-borne diseases associated with corn serve here as examples of the contrasting role of weeds in the dynamics of insect pest populations and disease incidence in crop production systems utilizing high technology agricultural inputs. The corn/Johnsongrass *[Sorghum halapense* (L.) Pers.] /maize dwarf mosaic virus (MDMV)/ aphid vector interrelationship is one example of this situation. Johnsongrass, an important overwintering and early spring host of MDMV (Williams and Alexander, 1965), is commonly found in and around no-till fields, and is phenologically more advanced by several weeks compared with conventionally tilled fields. Weed growth in no-till fields is not delayed compared with that in conventionally tilled fields (All and Musick, 1986).

The corn leaf aphid, *Rhopalosiphum maidis* (Fitch) is one of several aphid vectors of MDMV (Gordon, 1976). and feeds preferentially on Johnsongrass early in the spring before and after corn is planted before moving to corn (Nault. 1976). Aphids acquire the MDMV from Johnsongrass and transmit the virus to corn.

Several tactics are used to control MDMV in high-input production systems, all of which seek to disrupt the virus/vector/Johnsongrass/corn interaction. The most economically feasible options are the use of virus resistant corn varieties and early planting (Pitre, 1970). which allows corn to escape virus infection during its most susceptible stages and before large vector population build up. The use of conservation tillage in corn production may be impractical in areas with a history of MDM disease, large vector populations, and high density of insect vector non-crop host vegetation. However, rotation of soybean with corn allows for aggressive weed control to be implemented during the soybean portion of the rotation (All and Musick, 1986), which may be effective in reducing levels of MDM disease in the corn crop.

Thus, the presence of overwintering reservoir and early season weed host plants for virus disease agents and susceptible growth stages of the crop are requisites to the establishment of epiphytotics in corn production systems. Conversely, situations do exist where non-crop vegetaion can have a negative influence on crop disease severity and crop losses due to disease. Corn stunt disease, caused by the corn stunt spiroplasma, formerly recognized as corn stunt virus, was responsible for reductions in corn production in some parts of the southeastern United States in the 1960's (Gordon, 1976). The disease is transmitted to corn by several leafhopper species, including the black-faced leafhopper, *Graminella nigrifrons* (Forbes) (Boyd and Pitre, 1969).

Many grasses (weeds) serve as feeding host for G. *nigrifrons* (Table I. from Boyd and Pitre, 1969). Survival of adults varies depending on the host plant. Of the grasses encounttered in and around corn fields in Mississippi, survival was highest (20-33%) on orchardgrass *(Dactylis glomerata* L.) and crabgrass *(Digitaria sanguinalis* L.), and lowest (6-18%) on Johnsongrass, goosegrass *(Eleusine indica* L,), and lowest (6-18%) on Johnsongrass, goosegrass *(Eleusine indica* L.), bracharia *[Bracharia platyphylla* (Griseb.) Nasb.], Bahia grass *(Paspalum notafum* Flugge), common Bermudagrass *[Cynodon dactylon* (L.) Pers.], Dallisgrass *(Paspalum dilatatum* Poir.), and carpetgrass *(Axonopus affinis* Chase). Adult *G. nigrifrons* survival was generally poor on most of the plant species, including some cultivated crops tested by Boyd and Pitre (1969).

Corn is not a preferred feeding host of *G. nigrifrons.*

Table 1. Adult survival of and oviposilion by *G. nigrifrons* on various plant species after a 10-day confinement.*

Plant selection	No. eggs**	% survival**
Sorghum. Sweet Sioux	51.7 abc	33.1 a
Rice, Nato	54.3 ab	32.0 a
Ryegrass. perennial	10.3 def	31.0 a
Fescue, tall	5.0 det	27.4 a
Sudangrass, greenleaf	24.9 abcde	21.2 ah
Ryegrass. annual	9.3 def	27.2 ab
Barley. Colonial	27.5 abcd	27.1 ab
Millet. common pearl	67 2 a	24.5 ab
Orchardgrass	16.8 bcdef	24.2 ah
Sudangrass, sweet	19.1 abcdef	22.5 ab
Wheat. Anderson	14.9 bcdef	21.3 ab
Rye. Abruzzi	16.6 bcdef	20.7 ah
Crabgrass. large	14.9 bcdef	20.6 ab
Oat. Moregrain	56.1 ab	20.5 ah
Sugarcane	18.2 bcdef	18.0 ah
Johnsongrass	26.0 abcde	16.4 ab
Sorghum-Sudangrass hybrid. Suregraze	20.7 abcdef	16.1 ab
Corn, Mcurdy M-306	17.1 bcdef	16.1 ab
Coker 67	24.2 abcdef	15.7 ab
Seneca Chief	23.0 abcdef	15.4 ab
Funk's G-740	11.4 cdef	15.1 ab
Goosegrass	4.7 def	13.3 ab
Gamagrass, eastern	1.1 f	12.9 ab
Corn. Pioneer 309B	22.3 abcdef	12.9 ab
Bahiagrass. Pensacola	13.5 bcdef	12.6 ab
Bermudagrass, common	8.3 def	10.6 abc
Dallisgrass	21.9 abcdef	8.7 abc
Carpetgrass	2.3 def	8.2 abc
Brachiaria	3.0 def	5.5 bc
Alfalfa	1.5 ef	0.0 c

* Five males and five females per replicate.
** Average of 4 replicates; avg. % survial is the decoded arc sin mean and avg no. eggs is the decoded. square root + 0.5, mean.
Column means followed by the same letter are not significantly different at the 5% level of probability as determined by Tukey's w-procedure. Data modified from Boyd and Pitre (1969).

Where weed populations were regulated in small field plots in a corn field with a history of corn stunt disease in Mississippi, indigenous leathopper vectors were more abundant in weedy plots than in moderately weedy or weed-free plots (Table 2, from Pitre and Boyd, 1970). The influence of weeds on the leafhopper vector population was reflected in the disease incidence date (Table 3, from Pitre and Boyd, 1970). Disease incidence was higher in weed-free plots than in the other plots. Bracharia, goosegrass and crabgrass appeared to be the species of importance in the epidemiology of corn stunt disease in this field study in Mississippi. This fact suggests that the vectors showed preferential feeding on vegetation other than the corn crop. An increase in disease incidence can result in fields where vectors of disease agents have little choice in feeding. *G. nigrifrons* may feed on corn in weed-free fields because of the lack of a preferred food source. Thus, Pitre (1969) suggested that within-field weeds may be beneficial in reducing the incidence of corn stunt disease in corn in fields in Mississippi.

Both chemical and cultural methods are available to reduce crop losses due to corn stunt disease (Pitre, 1968). Although chemical control methods may be employed

Table 2. Number of *G. nigrifrons* collected from corn having received different weed-control practices. Yazoo City, Mississippi, 1968.

	Avg no. leafhoppers/ 125 linear row ft.			
Treatment	May 29	June 4	June 11	Seasonal Avg
Weedy	12 a	400 h	375 b	262 h
Weed-free	5 a	74 a	207 a	95 a
Moderately weedy	6 a	57 a	213 a	91 a

*Average of 4 replicates. Means followed by the same letter arc not significantly different at the 5% level by Duncan's multiple range test. Data modified from Pitre and Boyd. (1970).

Table 3. lncidence of corn stunt disease and yield of corn having received weed control practices. Yazoo City, Mississippi, 1968.

	Disease	Incidence	Yield
Treatment	July 9	August 5	lb/5 plants
Weedy	10 a	13 a	2.6 a
Weed-free	21 h	24 h	2.8 a
Moderately weedy	11 a	13 a	3.0 a

* Average of 4 replicates: includes plants in both the 2 and 3 rating class. Means followed by the same letter are not significantly different at the 5% level as determined hy Duncan's multiple range test. Data modified from Pitre and Boyd (1970).

routinely to protect corn crops from insect pests, other approaches including cultural control methods are available. Cultural controls entail modification of habitats which can create or destroy ecological niches for either pest or beneficial species (Herzog and Funderburk, 1985). Thus, a single factor or combination of methods may be used to regulate insect pests and associated plant diseases.

Conservation tillage methods can help reduce corn stunt disease losses by allowing non-crop vegetaion to develop in the field (Pitre, 1969), since *G. nigrifrons* prefers to feed on weeds rather than on corn plants. In this case, the leafhoppers might remain on weeds, feed less on corn, and lower the incidence of corn stunt disease transmission. In support of this hypothesis, Pitre (1969) and Pitre and Boyd (1970) reported that while weedy corn plots had the highest numbers of *G. nigrifrons* , these plots had a lower incidence of disease than weed-free plots. They suggested that in weed-free fields, *G. nigrifrons* had little option but to feed on corn, a less preferred host: thus the incidence of corn stunt disease was highest where effective weed control practices were followed.

Conclusions

Non-crop vegetation in conservtion tillage and no-tillage systems plays an important role in the dynamics of insect pest and natural enemy populations. Weeds serve as refugia, oviposition sites and sources of food for insects (Hammond and Funderburk, 1985), as well as host reservoirs for plant disease causal agents. This non-crop vegetation will enhance the structural and trophic diversity of the crop agroecosystem and crop damage due to pests may be increased or decreased depending upon the spatial and temporal biological relationshops between the plant and animal communities. These conservation tillage systems commonly support higher species diversity and density of insects than conventionally tilled systems.

The levels of crop and integrated pest management practices employed in crop production are basically limited by financial constraints in low technology agriculture, and by social, environmental and limited agronomic constraints in high technology cropping systems. Whereas there are disadvantages to utilizing conservation tillage practices, there are obvious benefits to no-till agriculture. Although the advantages of weedy fields are apparent for control of certain insect pests (e.g., limited feeding by leafhopper vectors on crop plants) and associated diseases (e.g., reduced incidence of corn stunt), this management technique will not be easily accepted among agricultural scientists or producers (Herzog and Funderburk, 1985). However, 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).

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Population Densities of Plant-Parasitic Nematodes in Multiple-Cropping and Tillage Systems

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Abstract

Hairy vetch *(Vicia sativa* L.) succeeded by corn *(Zea mays* L.) or grain sorghum *(Sorghum bicolor* L. Moench) were seeded in split plots randomized within whole plots of no-tillage versus conventional tillage over four growing seasons (1980-83). The vetch-corn cropping system increased the density of *Meloidogyne incognita* 2.9 X more than the vetch-grain sorghum cropping system. In contrast, the vetch-grain sorghum cropping system increased density of *Criconemella ornata* 0.7 X more than the vetch-corn cropping system. *Meloidogyne incognita* and *C. ornata* were affected more by these cropping systems than were *Pratylenchus hrachyurus* or *Paratrichordorus minor*. Multiple cropping systems, and crop host preference affected nematode population densities, whereas tillage treatments, conventional or no-tillage, had little effect on them.

Introduction

Minimum tillage and multiple cropping systems are being adopted rapidly by agriculturists in the southeastern United States (Gallaher, 1980), but few reports exist on their effects on population densities of plant-parasitic nematodes (Stinner and Crossley, 1982; Johnson, 1985). Yet, considerable progress was made during the past 20 years in characterizing the relationships between nematode densities and plant growth and yield in conventional agricultural systems (Barker and Olthof, 1976).

Population densities of *Meloidogyne incognita* and *Paru-frichodorus christie* were not affected bv tillage methods in field corn *(Zea mays* L.), (Fortnum and Karlen, 1985). Control of *M. incognita* in minimum tilled soybean *(Glycines mar* L. Merrill) was similar to that obtained in conventional tilled soybean (Minton and Parker, 1987). Greater population densities of *Pratylenchus scribneri* were reported in conventional tilled soybean than in no-tilled (Alby et al., 1983). Of seven tillage regimes tested, the greatest numbers of nematodes usually occurred in no-tilled ridge plots, and the lowest numbers generally occurred in spring-fall-plowed plots (Thomas, 1978). Our objective was to determine the effect of long-term double cropping and tillage systems on the population dynamics of plant-parasitic nematodes.

Materials and Methods

Hairy vetch *(Vicia sativa* L.) succeeded by corn and grain sorghum *(Sorghum bicolor* L. Moench) was grown in split plots randomized within whole plots no-tillage versus conventional tillage over five growing seasons (1979-83). Treatments with and without subsoiling were included in both tillage systems and were replicated four times. Each split plot was 25 ft. long and 45 ft. wide. From 1979 to 1981 the cropping systems included vetch succeeded by corn or by grain sorghum. Crops included hairy vetch, 'DeKalb XL71' corn and 'DeKalb BR64' sorghum. In 1982 and 1983 plots planted previously to corn or sorghum were split between corn and sorghum.

The soil was an Arredondo loamy sand (89% sand, 6% silt, 5% clay, 1.1% organic matter; pH 6.2; loamy siliceous,

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hyperthermic, Grossarenic Paleudult). Each fall the plots were harrowed three times and 30 Ib. A^{-1} of hairy vetch was drill planted in rows spaced 7 inches apart. The vetch was topdressed with 20-16-85-4-2 Ib. A^{-1} of N-P-K-Mg-S plus 4.5 Ib. A^{-1} Frit 503 and killed with paraquat in late March or early April.

In conventional tillage plots the soil was rototilled twice before planting. Grain sorghum or corn was planted directly into no-tillage or conventional tillage plots in 2.5 ft-wide rows with and without subsoiling using a two-row Brown-Harden Super-Seeder[3]. Fertilizer and herbicide applications and planting or corn and grain sorghum were done in a single operation (Corella et al., 1988). When the sorghum was about 5 inches tall a post-emergence application of atrazine 2.0 Ib. a.i. A^{-1} was broadcast over the sorghum. Both corn and grain sorghum received at least one post directed application of herbicides: ametryn 1.0 Ib. a.i. A^{-1} and 2, 4-D, 0.5 Ib. a.i. A^{-1} for additional weed control when plants were about 20 inches tall.

Soil samples for nematode assay were taken from the two middle rows of each plot yearly when each crop was at or near harvest. Samples from the crop rhizosphere 6-8 inches deep were taken with a sampling tube (1 inch diameter), 20 cores composited from each plot. Samples were placed in plastic bags and stored at 50°F until processed 2-5 days after sampling. The soil was mixed and a 1/2 pint aliquant was processed by sugar-flotation-centrifugation (Jenkins, 1969). Root samples consisting of bulked roots from five or more plants selected at random from each plot were also assayed (Endo, 1959). Nematodes were counted and identified to species. Roots of 20 plants from each plot were rated for root-knot nematode galling based on the following scale: 0 = no galls; 1 = 1-2; 2 =3-10; 4= 31-100; and 5 = > 100 galls per root system (Taylor and Sasser, 1978). All data were subjected to analysis of variance and treatment means were compared by Duncan's new multiple-range test. Differences referred to in the text were significant at ($P < 0.05$).

Results and Discussion

The mean population densities of *M. incognita* second-stage juveniles and *Pratylenchus bruchyurus* averaged over 4 years were 3.9 X and 1.9 X higher, respectively, under vetch-corn double cropping than under the vetch-grain sorghum double cropping system (Table 1). *Meloidogyne incognita* or *P. brachyurus* were not affected by tillage. In contrast, mean population densities of *Criconemella ornata* were 1.7 X higher under the vetch-grain sorghum cropping system compared to the vetch-corn double cropping system. The numbers of *Paratrichodorus minor* and *P. brachyurus* in roots in the soil were not affected by either cropping system or tillage system. The root-gall index was higher under vetch-corn cropping than vetch-grain sorghum cropping. Tillage treatments did not influence the root-gall index.

The mean nematode population densities were also affected by the crop species grown in the two cropping systems (Table 2). Population densities of *M. incognita* were higher when corn was growing in the field than when grain sorghum was growing. In contrast, *C. ornata* population densities were higher under grain sorghum than under corn, whereas, *P. minor* and *P. brachyurus* soil population densities were not influenced by the crop species. Vetch had lower root-gall indices when it was preceded by sorghum than when it was preceded by corn. The mean number of *P. brachyurus* in vetch roots was higher following corn than grain sorghum. The numbers of *P. brachyurus* in grain sorghum and corn roots were not different.

When plots planted previously to corn or grain sorghum were split, half corn and half grain sorghum, the mean number of *M. incognita* juveniles in the corn-vetch-corn-cropping system was 2.9 X that in the sorghum-vetch-corn system, and 7.1 X that in the sorghum-vetch-grain sorghum cropping system (Table 3). The mean number of *M. incognita* in the corn-vetch-grain sorghum was 2.6 X that in the sorghum-vetch-sorghum cropping system and sorghum-vetch-corn was 2.8 X that in the sorghum-vetch-sorghum cropping system. The mean number of *C. ornata* was highest in the sorghum-vetch-sorghum system compared with the other cropping sequences, whereas it was lowest in the corn-vetch-corn system. *Pratylenchus brachyurus* had a higher mean number in the corn-vetch-corn and corn-vetch-sorghum than in the sorghum-vetch-corn and the sorghum-vetch-sorghum system. *Paratrichodorus minor* did not respond to any of the systems tested.

A significant response in the population densities of two

Table 1. Soil or root population densities of four nematode species averaged over 4 years following a vetch-corn or vetch-sorghum cropping system each grown in no-tillage or conventional tillage with or without subsoiling.

Cropping system	Avg. no. nematodes/pint soil[1] *Criconemella ornata*	*Meloidogyne incognita*	*Parutrichodorus minor*	*Pratylenchus brachyurus*	Root-gall index[2]	*Pratylenchus bruchyurus* per 0.1 oz. roots[2]
Vetch-corn	130*	82*	51 NS	28 NS	3.3*	65.5*
Vetch-sorghum	215	21	48	24	1.5	34.9

*Significant differences between cropping systems according to F test ($P < 0.05$).

[1]Each mean is an average of four replications x four tillage treatments x 13 sampling dates.

[2]Each mean is an average of four replications x four tillage treatments x eight sampling dates. Root-gall index: 0 = no galling, 1 = 1-2, 2 = 3-10. 3 = 11-30, 4 = 31-100, 5 = > 100 galls per plant.

Table 2. Soil or root population densities of four nematode species averaged over 4 years following a corn or grain sorghum each grown in a cropping system of no-tillage or conventional tillage with or without subsoiling.

Cropping system	Crop	Avg. no. nematodes/1/2 pint soil[1] *Criconemella ornata*	*Meloidogyne incognita*	*Paratrichodorus minor*	*Pratylenchus brachyurus*	Root-gall index[2]	*Pratylenchus brachyurus* per 0.1 oz. roots
Vetch-corn	Vetch	190*	17*	40 NS	33 NS	3.1 a	92.4
	Corn	134	151	38	43	3.6 a	44.8 a
Vetch-sorghum	Vetch	263*	8*	25 NS	23 NS	0.8 b	23.0 b
	Sorghum	242	41	29	29	2.9 a	43.9 a

*Significant differences between crops within a cropping system according to F test (F < 0.05). NS = nonsignificant.
'Each mean is an average of four replications x four tillage treatments x 13 sampling dates.
'Each mean is an average of four replications x four tillage treatments x8 sampling dates. Numbers in columns followed by the same letter are not significantly different according to DMRT (p <0.05). Root-gall index: 0 = no galling, 1 = 1-2.2 = 3-10, 3 = 11-30. 4 = 31-100, 5 = < 100 galls per plant.

Table 3. Soil population densities of four nematode species following the final crop of a four multiple cropping system each grown in no-tillage or conventional tillage with or without subsoiling.

Cropping system	Avg. no. nematodes/l/2 pint soil *Criconeme ornata*	*Meloidogyne incognita*	*Paratrichodorus minor*	*Pratylenchus brachyurlcr*
Corn-vetch-corn	155 d	128 a	8 a	32 a
Corn-vetch-sorghum	230 c	46 b	8 a	40 a
Sorghum-vetch-corn	290 b	50 b	10 a	9 b
Sorghum-vetch-sorghum	334 a	18 c	8 a	9 b

Data in columns followed by the same letter are not significantly different according to DMRT (P < 0.05). All means are an average of four replicates x four tillage treatments x two sampling dates.

nematodes was caused by tillage treatments on only two sampling dates. Total nematodes were higher in no-tillage plots on both of these dates (average of 92 and 40 total nematodes per 1/2 pint of soil for no-tillage and conventional tillage, respectively). No individual nematode species had difference in population densities related to tillage. Effect of tillage treatment on nematode population densities depended on the cropping system and the vetch-grain sorghum cropping system had more effect than vetch-corn cropping system. This was attributed to the higher population density of *C. ornata* in the vetch-grain sorghum cropping system. Nematode population densities responded to tillage only when hairy vetch was growing in the field and the preceding nematode counts were the highest found among all sampling dates.

Grain sorghum suppressed *M. incognita* better than corn for succession double cropping with vetch when moderate to high population densities of *M. incognita* were present; however, when C. *ornata* was present in high population densities and *M. incognita* were absent or few in numbers. the vetch-corn double cropping sequence was best. Only two of 18 sampling dates showed a significant response in the populations of nematodes to tillage. Ring nematode was affected by tillage management more than the other nematodes, and this nematode was higher in no-tillage plots.

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Effect of Insects and Slugs on No-till Seeding of Landino Clover in Grass Pastures

G.D. Buntin and A.E. Smith[1]

Introduction

The establishment of forage legumes in grass pastures is desirable to improve forage quality and reduce the need for nitrogen fertilization. No-tillage establishment or sod-seeding of forage legumes such as ladino clover *(Trifolium repens* L.) and alfalfa *(Medicago sativa* L.) into grass sod reduces soil erosion during establishment, but grass competition. insect and slug damage can limit seedling establishment (Grant et al. 1982; Hoveland et al. 1982; Rogers et al. 1983, 1985: Wolf et al. 1983).

Suppression of grass competition by band or broadcast applications of paraquat or glyphosate enchances legume seedling survival and growth when interseeded into grass sod. Insects also have been associated with reduced legume seedling establishment in grass sod with damage often being associated with crickets, primarily *Allonemobius* spp, and *Gryllus* spp. (Grant et al. 1982; Rogers et al. 1983, 1985: Byers et al. 1985).Grasshoppers, armyworms, leafhoppers and plant bugs also may injure sod-seeded forage legume seedlings. Slugs can substantially reduce no-tillage establishment of legume seedlings in grass sod in the northern United States (Grant et al. 1982, Byers and Templeton, 1988). Insect and slug populations often are largest in late summer and early autumn, consequently late fall, winter and spring plantings usually avoid severe insect and slug damage (Rogers el al. 1983. 1985; Byers et al. 1985: Byers and Templeton 1988). At-planting application of a systemic insecticide and broadcast applications of a molluscicide have been found to reduce losses by insects and slugs to sod-seeded legumes (Rogers et al. 1983, 1985).

Sod seeding of ladino clover into tall fescue *(Festuca arundiacea* Schreb.) sod bas limited success in the Piedmont region of Georgia. Insect and slug damage are suspected as factors limiting no tillage establishment of forage legumes. We examined the effect of these factors and time of planting on the establishment of ladino clover seedlings in grass sod.

Materials and Methods

The effect of planting time. insect and slug control on the no-till establishment of 'Regal' ladino clover in a grass pasture was examined during 1985-1986 at the Beckham Research Farm located near Griffin, GA. The pasture was a 20 years old stand of tall fescue that had been managed mostly for hay production. Soil type was a cecil sandy clay loam (Typic Hapludult). Clover was slot-seeded in 10 inch rows at 5 lb of seed/acre using a Tye Pasture Pleaser grain drill. Vegatation was suppressed in a 4 inch band over the row in all treatments with Paraquat at 0.5 lb (Al)/acre plus X-77 . Treatments were three planting times (9 October, I November and 25 February) and a factorial combinaton of insect and slug control. Insects were suppressed with a broadcast application of carbofuran (Furadan) 15G at 2 lb (AI)iacre and a foliar application of carbofuran 4F at I.0 lb (AI)iacre on the day after planting and 10 days after planting, respectively. Slugs were controlled by broadcasting metaldyhde bait (3.3%) at 2 Ib (AI)/acre at I and 10 days after planting. A split plot experimental design was used with whole plots as planting dates and split plots as a factorial combination of insect and slug control. Whole plots were arranged in a randomized complete block design with four blocks with split plots measuring 20 x 30 ft.

Clover seedling number was measured periodically after planting by counting the number of plants in four randomly selected 1.6 ft. sections of row in each subplot. Foliage inhabiting insects also were sampled with a 15 inch diam. sweep net by taking 10 pendulum sweepsisubplot. Cricket populations were assessed by sampling all crickets in 2 randomly selected 2.69 ft.^{2} area/subplot. Slugs were trapped using a shingle trap which consisted of a 5 inch diam. x 6 inch hole in the soil covered with a 1 ft roofing shingle that was wrapped in aluminium foil (Schrim and Byers 1980). Shingles were left in the field, and traps were sampled when clover counts were made.

Plant number at about 4 weeks (27-33 days) after planting and insect counts after about 2.5 weeks (15-19 days) after planting were analyzed with an overall analysis of variance to assess the effect of planting date. Plant and insect counts also were analyzed by planting date and sample period with an

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analysis of variance for a factorial design. Very few slugs were collected throughout the study and insect populations were not affected ($P > 0.05$), therefore results were pooled among slug control teatments. Insect control means were compared using Least Significant Difference (LSD).

Effect of method of applying carbofuran at planting to control insects in seedling 'Regal' ladino clover seedlings interseeded into grass pasture was examined in a second study at the Dempsey Research Farm located near Griffin, Ga. The pasture consisted of a 25-year-old stand of primarily tall fescue. Soil type was the same as in the first study. Clover was seeded and grass was suppressed with Paraquat as described in the in the planting date study. Carbofuran was applied at planting by three methods: granules (15G) broadcast, granules applied in furrow, and broadcast foliar application of Furadan 4F. Granules were broadcast with a hand-held shaker, and in-furrow applications were made with a fertilizer box mounted on the grain drill. Foliar spray was applied with a small-plot sprayer equipped with No. 4 flat fan nozzels which delivered 29 gal/acre. Carbofuran was applied by each method at rates of 0.5, 1.0 and 2.0 Ib (AI)/acre. Treatments were a factorial arrangement of application method and rate with an untreated control also included. Treatments were arranged in a randomized complete block design with four replications.

Clover was interseeded on 25 September 1985, and clover densities were sampled 23, 30, and 43 days after planting. Insect populations were sampled on the first two dates. Clover and insect sampling procedures were the same as in the planting date study. Plant and insect counts were analyzed by sample period with an analysis of variance of all treatments. If the treatment F-value was significant ($P < 0.05$) main effects of application method and rate were analyzed using an analysis of variance for a factorial design.

Results and Discussion

The predominant foliage inhabiting insects were leafhoppers and aphids, primarily the pea aphid, *Acrythosiphon pisum* (Harris). Predominant leafhoppers were *Exitianus exitious* (Uhler), *Graminella nigrifrons* (Forbes), *Graminella sonora* (Ball), *Polyamia weedi* (Van Duzee) and the clover leafhopper, *Aceratagallia sanguinolenta* (Provancher). *A. sanguinolenta* feeds mostly on legumes whereas the other species feed primarily on grasses Predominant cricket species were *Allonemobius fasciatus* DeGeer) and *Gryllus* spp. and grasshoppers were mostly *Melanoplus* spp. Very few

Table 1. Effect of insect control at planting with carbofuran in insect populations in ladino clover interseeded into tall fescue sod.

Planting date	Sample period (days after planting)	Insectide treatment	Taxa: Crickets	Leafhoppers	Aphids	Grasshoppers
Oct. 9	9	Untreated	5.0	20.1	0	0.1
		Treated	1.6	10.5	0	0.1
		LSD	3.2	8.9	NS	NS
	16	Untreated	3.3	26.1	0	0.4
		Treated	2.0	13.5	0	0.1
		LSD	NS	NS	NS	NS
	21	Untreated	2.9	6.1	1.0	0.4
		Treated	1.5	4.9	0.5	0
		LSD	NS	NS	NS	0.3
Nov 1	19	Untreated	1.5	18.1	141.0	0.1
		Treated	0.8	5.4	3.4	0
		LSD	NS	8.0	27.2	NS
	29	Untreated	2.3	3.6	1.1	0
		Treated	1.8	1.3	0.9	0
		LSD	NS	2.0	NS	NS
	57	Untreated	0	0	0	0
		Treated	0	0	0	0
		LSD	NS	NS	NS	NS
Feb 25	15	Untreated	0	1.8	6.6	0
		Treated	0	0.1	0.3	0
		LSD	NS	1.0	4.8	NS
	22	Untreated	0	2.0	5.5	0
		Treated	0	2.1	1.4	0
		LSD	NS	NS	NS	NS
	33	Untreated	0	3.2	7.3	0
		Treated	0	3.1	4.2	0
		LSD	NS	NS	NS	NS

NS = Not significant ($P = 0.05$; LSD).

slugs, *Deroceras* spp., were collected during the fall planting but none was collected in the winter planting.

Planting date significantly affected leafhopper ($F = 8.12$, $P = 0.02$) and aphid ($F = 96.71$. $P < 0.01$) densities with leafhoppers being most abundant in the 9 October planting and aphids being most abundant during the 1 November planting (Table 1). Grasshoppers were collected in low number only during the first fall planting. Crickets were significantly ($F = 8.39$, $P = 0.02$) more abundant during the fall plantings than the winter planting when none was collected. Insecticide usage significantly reduced leafhopper and aphid numbers at the first sample time in all plantings (Table 1). Cricket numbers were lower in treated than untreated plots in all sample where crickets were collected, but the reduction was significant ($P < 0.05$) only for the initial sample time in the October planting (Table 1).

Plant density reached a peak 2-3 weeks (Days 15-19)after planting and declined thereafter in all plantings (Table 2). Plant density about 4 weeks (27 — 33 days) after planting was significantly ($F = 18.77$, $P < 0.01$) greater in the February than the fall plantings. Plant number was not significantly ($P = 0.05 - 0.92$) affected by insect or slug control in any planting date. Futhermore, the rate of decline in seedling number from the peak number was not affected by pesticide usuage (Table 2). Clover density declined on average by 50.0, 60.3 and 50.8 % in the October, November, and February plantings, respectively. Despite a similar rate of stand lost, the February planting resulted in many more seedlings than the fall plantings with few seedlings remaining on the last sample period in the fall plantings.

Predominant foliage inhabiting insects in the second study were leathoppers and crickets. Foliar applications of carbofuran reduced leafhopper densities at 18 days after planting but not at 30 days after planting. Granular treatments did not consistently reduce leafhopper numbers on either sample date. Cricket, primarily *A. fasciatus* numbers generally were lower in treated than untreated plots, but were not significantly ($P<0.05$) different between treatments on any date (data not shown).

Clover plant number in the second study peaked at 30 days after planting and declined thereafter (Table 3). Plant density was not significantly different between treatments at 23 and

Table 2. Effect of insecticide (IN) and molluscicide (MO) application at planting of the stand density of ladino clover interseeded into tall fescue sod at three planting dates.

Planting date	Sample date[a] (days after planting)	None	IN	Treatment MO	IN+MO	P>F
		~L /row m				
Oct. 9	9	13.6	12.1	13.7	14.5	NS
	16	22.8	21.1	17.9	17.3	NS
	27	10.3	10.4	8.7	9.Y	NS
	48	2.1	2.0	2.0	2.5	NS
	Reduction (%)	54.8	50.7	51.7	42.8	NS
Nov 1	19	8.5	6.8	7.5	11.0	NS
	29	1.9	3.5	3.6	4.1	NS
	57	.06	0.4	0.1	0.3	NS
	Reduction (%)	77.7	48.4	52.0	62.8	NS
Feb. 25	15	82.9	99.9	93.5	80.0	NS
	22	78.8	68.3	65.4	67.5	NS
	33	43.9	52.9	35.3	42.X	NS
	Reduction (%)	471I	471I	6213	4616	NS

[a] Reductions were calculated from days 16-27, days 19-29, and days 15-33 after planting for the Oct 9. Nov 1. and Feb 25 plantings. respectively

Table 3. Effect of application method and rate of carhofuran at planting on ladino clover plant number when interseeded into grass sod.

Application method[a]	Rate (lb(AI)/acre)	Days after planting 23	30	43	Stand Reduction[b]
		Plants/ No./row m			%
Untreated		34.7	50.0abc	21.5a	57.5ab
BC granules	0.5	37.2a	50.8abc	19.3a	61.6ab
	1.0	26.9a	44.1ab	24.1a	43.3bc
	2.0	33.7a	45.0ab	18.3a	59.9ab
IF granules	0.5	25.4a	39.5a	12.1a	71.2a
	1.0	29.8a	66.9c	21.0a	68.9a
	2.0	31.7a	58.5bc	25.6a	59.0ab
BC foliar	0.5	30.7a	50.7abc	20.5a	59.3ab
	1.0	29.4a	41.8ab	27.6a	35.1c
	2.0	25.3a	50.3abc	19.6a	60.3ab
P-values					
Method (M)		0.34	0.23	0.67	0.04
Rate (R)		0.73	0.54	0.04	0.02
M x R		0.24	0.01*	0.11	0.09

Means followed by the same letter are not significatly different ($P = 0.05$; LSD).
[a] BC = broadcast, IF = in-furrow
[b] Reduction from day 30 to day 43 after planting.

43 days after planting. Significant ($P = 0.03$) differences in plant number occurred between treatments at 30 days after planting, but no treatment was significantly different than the untreated control. The percentage reduction in plant number from 30 to 43 after planting was significantly ($P = 0.01$) affected by application method with stand reduction in the in-furrow treatments being greater than the reduction in the other methods and the untreated control. Use of carbofuran in this study did not enhance the establishment of ladino clover in grass sod regardless of the application method or rate.

These initial studies indicate that insects and slugs had little effect on the no-tillage establishment of ladino clover seedlings in grass sod. Fall no-till establishment of ladino clover was poor regardless of insect or slug control. The planting date study indicated that seedling establishment was greatest during the winter (February). Winter planting avoided most insect and potential slug damage. The consistent decline in seedling numbers after planting in the fall suggests a that some factor other than insects, slugs and grass competition reduced seedling establishment. Soil-borne pathogens or edaphic factors including seed-soil contract and moisture stress may limit no-till establishment of legume sedlings. Insect populations are sporadic and may substantially reduce establishment of sod-seeded legumes (Hoveland, 1981) but insect damage can be minimized by planting later in the fall or during the winter.

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Successes With No-Till Cotton

John F. Bradley[1]

Introduction

Eight years of research with no-till cotton at the University of Tennessee Milan Experiment Station have proven that no-till cotton can be produced successfully in previous crop stubble or in killed small grains that have been grown for winter cover. There have also been three to four thousand acres during the 1988 growing season demonstrating success on the farm by West Tennessee farmers.

During the past four seasons yields of no-till cotton have exceeded 2 bales per acre of lint cotton. During the 1987 growing season over 3 bales of lint cotton per acre were produced under the no-till system. This equalled the conventionally planted and cultivated cotton at Milan.

There are several advantages to no-till cotton that should be considered, (1) seedbed preparation is eliminated which can reduce the cost of production, as many as six trips across the field can be saved, (2) cotton can be produced on slopes not normally used for conventional crop, (3) soil erosion is effectively reduced on sloping land (4) all fertilizer and lime can be broadcast on the soil surface, (5) soil is firmer at harvest time with fewer harvesting delays due to weather. Proven steps in producing no-till cotton need to be adhered to in order to achieve high yields. (Table 1)

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Table 1. No-tillage vs conventional tillage cotton lint yields across variety trials planted into standing wheat or rye.

Year	No-till Lb/A	Conventional Lb/A
1981	273	382
1982	940	937
1983	508	336
I984	1071	1146
1985	1040	1048
1986	854	853
1987	919	987
1988	767	690
AVERAGE	797	197

Planting

Field selection should be on soils suitable for conventional tillage cotton. Fields with heavy infestations of perennial grasses such as johnsongrass or bermudagrass should either be avoided or the producer should plan to repeat applications of in-season grass herbicides.

Soil temperature is more critical for no-till cotton than conventional because the soil can be several degrees cooler depending on the thickness of the mulch. Ideal soil temperature is 68°F, 2 inches below the soil surface at 8:00 a.m. for three consecutive days. Research has shown in limited residue situations such as old crop stubble (cotton stalks in particular) the soil warms up as fast as that of aprepared tilled seedbed, resulting in no delay of planting. Winter cover crops such as wheat, rye or vetch should be killed 10-15 days prior to planting cotton, the soil will warm and dry faster.

Popular recommended cotton varieties usually perform well in no-till culture. Grades, staple length, and micronaire values have not been different than those obtained from the same varieties that have been conventionally tilled.

Good stands can be obtained in no-till cotton production. Six year average plant population has been approximately 75 percent that of conventionally planted seed from the same source. 2.5 to 3.5 stalks per foot of row are sufficient for optimum yields. This requires planting 6-7 seed per foot of row of 80 percent germ seed

Planting Equipment

Use only planters designed for no-till. The Milan Experiment Station uses a John Deer Max-Emerge planter, a Case-IH Early-Riser will work as well, as will an A-C No-Till planter. One ripple coulter from 3/4" to I" wide leading in front of the double disc openers works best. The coulter should be set to run one inch deeper than the double disc openers. The "rule of thumb" for coulter setting: the dryer the soil the deeper the coulter setting, the wetter the soil the more shallow the setting.

The double disc openers need to be followed by heavy duty press wheels with pressure enough to cover the seed firmly. Planting should be 4-5 MPH. Weight may need to be added to the planter when soil conditions are dry or hard.

A soil treatment of an insecticide (Temik) plus a soil fungicide (Terraclor Super X) is a must in no-till cotton. Use recommended rates of soil treatments such as Ridomil PC plus Temik, TSX plus Di-Syston, Temik-TSX or TSX in-furrow followed with foliar treatments after cotton emergence for thrip and aphids.

Fertilization

As always a good fertility program is necessary. Soil test and apply lime, phosphate and potash in the fall or early spring. Nitrogen should be applied broadcast just prior to planting at the rate of 60-80 units per acre. Use soil test and common sense to adjust nitrogen rates according to field history, ie. if cotton grows rank in a field, cut back on nitrogen.

Herbicides

A complete kill of all vegetation prior to or at planting is essential. In most cases one quart of Roundup per acre is necessary for good control, especially if tough to kill annuals such as horseweed (marestail) or perennial weeds are present. Gramoxone Super plus surfactant works excellent on cover crops as wheat, vetch, clovers and annual weed.

Dual or Prowl should be used preemergence with Cotoran and/or Zorial. A surfactant can be included when these are applied to enhance foliar activity on emerged weeds. Dual has exhibited more activity than Prowl on spurges and nutsedges, while late annual grass control has been better with Prowl. Cotoran will be needed in most situations. Tank mixtures of Cotoran and Zorial have performed better where prickly sida, velvetleaf and spurges are present.

It will probably be necessary to post-direct the no-till cotton after the cotton is at least 6" tall and weeds are less than 2" tall for season long control. Johnsongrass can be controlled with over-top applications of Poast or Fusilade. Although it has not been necessary at the Milan Experiment Station, no-till cotton in old cotton, soybean or corn stubble can be cultivated successfully.

Insect and disease control has not been different with no-till compared to the conventional. A good scouting program always pays.

Cotton Yields as Affected by Previous Crop Tillage and Subsoiling for Cotton

J.T. Touchton, D.W. Reeves, and R.R. Sharpe[1]

Introduction

One of the biggest disadvantages of no tillage in the Southeastern Coastal Plains is the need for in-row subsoiling at planting. This need is created by tillage pans several inches below the soil surface and compaction in the surface few inches of soil. Both of these compaction problems can result in yield reductions if in-row subsoilers are not used at planting.

During the past few years research efforts have been directed towards finding methods of eliminating compaction problems without having to use the in-row subsoilers and without having to abandon conservation tillage. Data collected from these studies indicate that soybeans can be planted directly into wheat stubble on highly compactable soils if the soil is deep tilled (chisel, turned, or subsoiled) prior to planting wheat and if the soybean are planted in narrow row widths (24 inches or less) (Sharpe et at., 1988). This tillage system did not work for grain sorghum (Touchton and Bryant, 1988).

Other studies have shown that both corn and grain sorghum can be no-till planted on these compactable soils if the row middles are subsoiled a few weeks after planting

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(Reeves and Touchton, 1986; Touchton and Bryant, 1988). Although subsoiling is still required. this system will allow for faster planting during critical planting periods.

The objective of this study is to determine the effects of previous crop tillage and inter-row subsoiling on cotton yields.

Material and Methods

This study is located in the Coastal Plains of southern Alabama on a Benndale fine loamy sand, a Lucendale fine sandy loam, and a Dothan fine sandy loam at Auburn University's Brewton Experiment Field, Monroeville Experiment Field, and Wiregrass Substation at Headland, respectively. Tillage treatments consisted of no tillage, disk, chisel plow, moldboard plow, or subsoil on 36-inch center prior to drilling rye each fall. Tillage at cotton planting (Monroeville and Brewton only) consisted of none and inrow subsoiling 10 to 12 inches deep. Row width was 36 inches. The rye was cut and removed from the field just prior to cotton planting. Tillage 4 to 6 weeks after planting cotton consisted of between row subsoiling 10 to 12 inches deep and no subsoiling.

History of experimental sites: These plots were established in the fall of 1980 to determine the effects of tillage prior to planting wheat on the yield of double-cropped soybeans grown in conservation tillage systems. In 1984, the summer crop was changed to grain sorghum, which was double cropped with wheat harvested for grain. In the fall of 1986, the winter crop was changed to rye, and in the spring of 1987 the summer crop was changed to cotton. The rye is harvested for forage yields instead of grain so that cotton can he planted during the optimum planting periods. Although crops have changed over the years, the basic tillage systems (no-till, disk, chisel, and turn) are still on the original plots. and the 1988 cotton crop represents the 8th year of each tillage system and the second year of data for rye and cotton.

Results

Rye 1987 and 1988

Judging from 2 years of forage yields (Table I), it appears that rye has a greater need for deep tillage than wheat. Disking improved rye yields over that obtained with no tillage, but deep tillage was superior to disk tillage. As with wheat (Sharpe et al., 1988), there was not much difference in rye yields among deep tillage systems, which suggests that chisel plowing or just pulling a subsoiler with 36-inch subsoil shank spacings is as effective as turning. The date from Brewton and Monroeville suggest that rye will benefit from subsoiling the previous crop. This in-row subsoiling for the previous summer crop also improved wheat forage yields in previous tests, hut not wheat grain yields. Higher forage yields at Headland than the other locations were due to February applications of N at Headland but not the other locations

Cotton-1987

Seed cotton yields at each location in 1987 are listed in Table 2. Yield responses among tillage systems varied with locations

Brewton. In-row subsoiling regardless of previous tillage resulted in the best yields. With in-row subsoiling at cotton planting, yields fell into 4 groups, which are:

Previous crop tillage:	Between row subsoiling Yes	No
	— Seed cotton, lb/acre —	
No-till, Disk, Chisel	3060	3330
Turn. Subsoil	3260	3590

Evidently, waiting until cotton is 10 to 12 inches tall is too late for deep subsoiling between the rows. It also appears that cotton response to tillage prior to the previous winter crop is more like grain sorghum than soybean, in that subsoiling does not eliminate the benefits that deep tillage prior to planting the winter crop has on yields of the summer crop. In addition, for cotton as with sorghum, deep tillage prior to planting the winter crop did not eliminate the need for in-row subsoiling at planting. Seed cotton yield without in-row subsoiling averaged 2960 Ib/acre, which is 630 lb/acre less than the *best* group shown above.

Monroeville. Yields at Monroeville averaged 2500 lb/acre, but they were too erratic to draw conclusions about the effects of various tillage systems (Table 2). It does appear, however, that tillage systems did not have much effect on cotton yields.

Headland. Yields at Headland fell into 3 basic groups: I) when the in-row subsoiler was used (which resulted in the highest yields), there were no differences among tillage treatments prior to planting rye, and average yield was 2570 Ib/acre; 2) when the in-row subsoiler was not used, no-tillage and disk-tillage prior to planting rye resulted in the lowest yields (2140 lb/acre); and 3) there were not differences in yields (2310 lb/acre) among the 4 deep tillage systems.

Table 1. Rye forage yields as affected by tillage prior to planting rye and in-row subsoiling for the previous summer cotton crop.

Tillage at rye planting	Subsoiling previous crop	Headland 1987	Headland 1988	Brewton 1987	Brewton 1988	Monroeville 1987	Monroeville 1988
		--rye yield, lb/acre -					
No-till	Yes	3870	2429	1170	786	1700	760
	No	-----	-----	530	493	1700	765
Disk	Yes	4960	2429	1220	1399	2520	1500
	No	-----	-----	660	946	2690	1330
Chiscl	Yes	5690	2631	1400	2012	2680	1740
	No	-----	-----	1400	1866	3140	1570
Turn	Yes	5320	0744	1370	1652	2940	1840
	No	- ----	-----	860	1400	2890	1540
Subsoil	Yes	5320	3238	1450	1652	2700	1720
	No	-----	-----	1240	1586	2780	1580

Cotton-1988

Cotton yields in 1988 were not as responsive to treatments as in 1987 (Table 3). There was little relationship between previous crop tillage and cotton yield. The only striking response to in-row subsoiling at cotton planting occurred at Monroeville, which is unusual because yield responses to in-row subsoiling for any crop seldom occur at the Monroeville Experiment field. As in the previous year, there was

Table 2. Seedcotton yields in 1987 as affected by tillage prior to planting rye, in-row subsoiling at cotton planting, and between-row subsoiling when cotton plants were 10 to 12 inches tall.

Loc.	Subsoiling In-row	Subsoiling Between row	NT	Disk	Chisel	Turn	Sub[1]
			Tillage prior to planting rye				
Brewton							
	Yes	Yes	2940	3190	3050	3390	3290
		No	3260	3310	3210	3670	3610
	No	Yes	2590	2870	2900	3040	2760
		No	2960	2950	3170	2890	2930
Monroeville							
	Yes	Yes	2180	2540	2260	2420	2810
		No	2450	2380	2530	2610	2850
	No	Yes	2620	2310	2550	2630	2550
		No	2600	2300	2510	2440	2590
Headland							
	Yes	-2	2560	2430	2620	2510	2610
	No	--	2170	2100	2250	2310	2310

[1]Sub is subsoiling prior to planting wheat on 36-inch centers.
'Between-row subsoiling was not a treatment at Headland.

Table 3. Seedcotton yields in 1988 as affected by tillage prior to planting rye, in-row subsoiling at cotton planting, and between-row subsoiling when cottonplants were 10 to 12 inches tall.

Loc.	Subsoiling In-row	Subsoiling Between row	NT	Disk	Chisel	Turn	Sub[1]
			Tillage Prior to planting rye				
Monroeville							
	Yes	Yes	2870	2550	2610	2670	2860
		No	2830	2600	2730	2620	2500
	No	Yes	2670	2320	2510	2670	2630
		No	2580	2470	2720	2660	2700
Brewton							
	Yes	Yes	2180	2080	1930	2130	2090
		NO	2020	1990	1910	2140	2210
	No	Yes	2040	2200	1800	2390	2100
		No	2090	2450	2080	2310	2290
Headland							
	Yes	-2	1410	1530	1320	1810	1600
	No	.-	1560	1440	1520	1700	1470

[1]Sub is subsoiling prior to planting wheat on 36-inch centers
[2]Between-row subsoiling was not a treatment at Headland.

no benefit to between-row subsoiling after crop emergence.

Based on two years of data collected at 3 south Alabama locations, it appears that if cotton is grown on a soil that needs some type of deep tillage, the tillage will have to be done either prior to or at planting. Data from previous tests with corn (Reeves and Touchton, 1986) and grain sorghum (Touchton and Bryant, 1988) suggest that subsoiling row middles after stand establishment is a good substitute for in-row subsoiling at planting.

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Corn and Soybean Response to Conservation Tillage, Irrigation, and Short Term Crop Rotation

F.M. Rhoads[1]

Introduction

Crop rotation to increase yield has not been emphasized since adequate supplies of low cost nitrogen fertilizers became available. Recent research with crop rotation has been related mostly to soil erosion and water infiltration (Laflen and Moldenhauer, 1979) with yield response not reported in most cases.

There are several advantages and disadvantages of crop rotation listed by Kurtz et al. (1984). The most important advantages are: legumes provide a source of N for other crops, protection against soil erosion, improved aeration and drainage, increased water-holding capacity, better pest control, and elimination of autoallelopathy. Two main disadvantages are maximum land area is not available to highest value crop and more equipment is required that with a monocropping system.

Interest in crop rotation before low cost N fertilizer was mainly due to increased corn yields as a result of N supplied by a previous legume crop. However, corn yield increases of as much as 17% have been observed after soybean that could not be attributed to N from the legume (Welch, 1979 and Vandoren et al., 1976). Not much information is available on legume yields in response to rotation. However, soybean yields declined by 40% when grown continuously for three years in North Florida (Rhoads and Manning, 1989). Quantitative data showing yield response to crop rotation would be useful to crop producers in making management decisions of whether or not to rotate and how often to rotate.

Irrigation and conservation tillage practices have expanded quite rapidly during a period when crop rotation has not been widely practiced. Therefore, not much is known about yield response to crop rotation under irrigation or with conservation tillage.

The objective of this research is to determine yield re-

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sponse of corn and soybean to crop rotation and conservation tillage with and without irrigation.

Materials and Methods

This experiment was initiated in 1987 on a Dothan loamy fine sand on the North Florida Research and Education Center at Quincy.

Fertilizer rates were 500 lb of 0-10-20 per acre each year for both corn and soybean. Corn received 600 lb of ammonium nitrate per acre each year. Nitrogen was not applied to soybean.

Row width was 30 inches each year for both corn and soybean. Corn plant population was 30,000 plants **per** acre. Soybeans were planted about 2 inches apart in the drill.

DeKalb-Pfizer (DK689) corn was planted on March 17, 1987 and March 25, 1988 in both irrigated and unirrigated treatments. Soybean (Braxton cv.) was planted in both irrigated and unirrigated treatments May 27, 1987. Unirrigated soybean was replanted June 30, 1987 because of poor germination due to lack of rainfall. Soybean (Thomas cv.) was planted in irrigated plots June 14, 1988 and unirrigated plots were planted July 7 , 1988.

Irrigation was applied with a center pivot system in 1/2 inch increments when soil-water suction at the 6-inch depth exceeded 20 centibars. Unirrigated plots were outside of the area irrigated with the center pivot and adjacent to the irrigated plots.

Regular tillage (RT) included disking until weeds and crop residues were buried and using a S-tine cultivator with a crumbler attachment to level the seed bed before planting. Conservation tillage (CT) was accomplished with a subsoiler having fluted coulters to prepare a seed bed over the subsoiler slot. A two-row John Deer 71 planter was used to plant both regular and conservation tillage systems. The crop rotation plan is show in Table 1.

Table *1*. A four-year rotation plan for determining quantitative effects of tillage and cropping system on yield of irrigated and unirrigated corn and soybean.

Tillage	Year 1987	1988	1989	1990
RT†	Corn	Corn	Corn	Corn
	Soybean	Soybean	Soybean	Soybean
	Corn	Soybean	Corn	Soybean
	Corn	Corn	Soybean (Wheat)‡	Soybean
	Soybean (Wheat)$	Soybean (Wheat)$	Soybean (Wheat)‡	Soybean
CT	Corn	Corn	Corn	Corn
	Soybean	Soybean	Soybean	Soybean
	Corn	Soybean	Corn	Soybean
	Corn	Corn	Soybean	Corn
	Soybean	Soybean	Corn	Soybean

†RT = Regular tillage CT = Conservation tillage.
‡Wheat grown during winter months.

Roundup was used to control weeds on conservation tillage plots before crop emergence. Lasso and altrazine were applied postemergence to corn plots at the 2-leaf stage. Lasso and treflan were used for weed control in soybean.

Yield data arc reported at 15.5% moisture for corn and 12% moisture for soybean. Orthogonal contrasts were used for statistical comparison of treatment means (Steel and Torrie, 1960). The experimental design was a randomized complete block with four replications

Results and Discussion

Irrigated corn yields ranged from 179 to 201 buiacre in 1987 and from 181 to 205 bu/acre in 1988. (Table 2). Unirrigated corn yields in 1987 were about twice those of 1988. Higher soybean yields in 1988 than in 1987 may be due to variety difference (Table 2).

Table 2. Yield of irrigated and unirrigated corn and soybean grown continuously and in rotation with regular tillage (RT) and conservation tillage (CT) in 1987 and 1988.

Tillage	Rotation	1987 Irrig.	Unirrig.	Rotation	1988 Irrig.	Unirrig.
		bu/acre			bu/acre	
RT	Corn	201	94	Corn	197	50
	Soybean	*36*	36	Soybean	46	37
	Corn	180	107	Soybean	57	45
	Corn	194	119	Corn	205	41
	Soyhean?	42	35	Soybean?	56	35
CT	Corn	183	107	Corn	192	30
	Soybean	42	38	Soybean	45	39
	Corn	182	118	Soybean	54	45
	Corn	179	107	Corn	181	32
	Soybean	37	40	Soybean	42	40

†This rotation includes wheat during winter months.

Tillage did not influence (P >0. 10) irrigated corn yields in either 1987 or 1988. (Table *3)*. Unirrigated corn yields were not influenced by tillage in 1987 but conservation tillage reduced (P< 0.01) unirrigated corn yields in 1988. The yield difference is attributed to reduced runoff in RT plots because of inter-row cultivation prior to a significant amount of rainfall.

Table 3. Statistical analysis of tillage effects on irrigated and unirrigated corn yield in 1987 and 1988.

Source of Variation		Year	Average yieldt Irrigated	Unirrigated	F test†† Irrigated	Unirrigated
			bu/acre			
Tillage	RT‡	1987	192	107	P>0.10	N.S.
	CT	1987	181	111	2 29	0 35
	RT	1988	201	46	P>0 10	P<0.01
	CT	1988	187	31	13X	11 71

†Irrigation effects cannot be determined statistically because irrigation was not replicated.

††F values arc for comparing means within years. The probability of a greater F value is shown above eachF value.N.S. = not significant (F< 1.0).
SRT = regular tillage CT = conservation tillage.

Soybean yields were not influenced by tillage in 1987 nor were unirrigated yields in 1988 (Table 4). Irrigated soybean yield in 1988 was significantly (P<0.05) higher in RT plots than in CT plots. However, this was not a response to tillage but rather a response to rotation because the CT plots did not contain a wheat-soybean (WS) rotation. The WS treatment in 1988 irrigated soybean yielded about 20% greater than continuous soybean. Lack of response to the WS rotation in unirrigated soybean may be due to soil water depletion by the preceding wheat crop. Whereas, the soil was recharged by irrigation in the irrigation WS rotation. Yield of continuous soybean was about 20% less that corn-soybean with irrigation and about 13% less without irrigation.

Table 4. Statistical analysis of tillage and rotation effects on irrigated and unirrigated soybean yield in 1987 and 1988.

Source of Variation		Year	Average yield† Irrigated	Unirrigated	F testtt Irrigated	Unirrigated
			------bu/acre------			
Tillage	RT	1987	39	35	N.S.	P<0.10
	CT	1987	39	39	0.001	4.98
	RT	1988	53	39	P<0.05	P>0.10
	CT	1988	47	42	7.60	2.66
Rotation	SS[§]	1988	44	39	P<0.01	P<0.01
	CS	1988	55	45	18.34	11.71
	SS (RT)	1988	46	37	P<0.05	N.S.
	WS(RT)	1988	56	35	6.37	0.42

†Irrigation effects cannot be determined statistically because irrigation was not replicated. †† F values are for comparing means within years. The probability of a greater F value is shown above each F value. NS = not significant (F<1.0).
§RT = regular tillage, *CT* = conservation tillage, SS = continuous soybean, CS = soybean following corn SS (RT) = continuous soybean and regular tillage, WS (RT) = wheat in winter and soybean in bummer with regular tillage.

The rotation plan does not allow measurement of corn response to rotation until the third and fourth years of the experiment. However, continuous corn yields were about the same in 1988 as in 1987. Soybean response to rotation can be measured each year with the exception of year one when it was not possible to measure rotation effects in either crop.

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Starter Fertilizer Placement in No-Till Corn

D.L. Wright[1]

Introduction

The increase in use of conservation tillage cropping systems in the Coastal Plain began later than for much of the country because different tillage requirements were necessary on these compacted, sandy soils. It was not until the late 1970's that minimum tillage planters were perfected to the point to gain wide acceptance by farmers. These planters were equipped to perform deep tillage in the row while leaving row middles undisturbed. As tillage systems changed from conventional methods to minimum tillage methods, interest in optimum placement of fertilizer increased because of limitation in obtaining the standard 2 x2" placement for starter fertilizers. Several researchers in different parts of the country have shown yield responses to starter fertilizers on corn (Reeves et al., 1986; Rehm et. al., 1986). In studies conducted on Coastal Plain soils Touchton and Karim (1986) found increased early vigor and higher grain yields on corn from N-P fertilizers when applied behind the subsoil shank on an in-row subsoiler. Wright and Teare (1988) found that corn hybrids have a marked difference in their response to starter fertilizer with some hybrids giving little or no response while other hybrids give large yield increases. The hybrid response may account for variability in data within regions on similar soil types where starter fertilizer gave large increases at certain locations and little or none at others.

Better crop yields cannot always be attained by adjusting fertilizer rates alone but better placement often improves nutrient availability. Better nutrient use through placement can increase yield and cause other favorable results such as increased plant vigor and faster maturity. Positive benefits of nutrient placement especially from close placement at planting have been reported (Follett et al. 1981; Richards 1977).

Corn is the primary crop to which starter fertilizer (usually N-P combinations) is applied. When planting minimum till corn, residue may vary from little, if planting behind soybeans, to several tons of dry matter from rye or clovers. The factors that most influence P uptake in no-till corn is (1) temperature, and (2) soil compaction. Phosphorus absorption and diffusion to the roots is slower at low soil temperatures (Epstein, 1971). Large amounts of surface residue and higher soil moisture levels can reduce soil temperatures 3-5°C or more. High nutrient concentrations close to the developing plant can help overcome the slow root development and low P uptake. Untilled no no-till planted soils generally have a higher bulk density (more compaction) than tilled soils, and nutrient availability is depressed because of less root exploration. Close placement under these condi-

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tions will normally result in plant growth and yield responses.

Field studies were conducted from 1984 through 1988 to investigate starter fertilizer placement effects on corn grown under minimum tillage conditions of Coastal Plain soils.

Materials and Methods

This study was conducted on a Norfolk sandy loam (fine, loamy siliceous, thermic Typic Paleudults) located on the North Florida Research and Education Center. The soil has a compacted layer located 7 to 14 inches below the surface. These experiments were planted from early March to early April (March 14, 1984; March 1, 1985, March 26, 1986; April 6, 1987; and March 30, 1988). DeKalb XL748 was used in each year except 1988 when Pioneer Brand 3165 was planted. These studies were conducted under an intensive management system where sufficient nutrients were broadcast to meet soil test recommendations and then starter fertilizer (10-34-0) at 10 gal/acre was applied at different locations near the row. Four row plots were 25 feet long planted at 30,000 plants/acre in each of four replications. The studies were irrigated on schedule when tensiometers dropped below 20 centibars of soil was tension. Two sidedress applications of N were made to bring total N to 240 lbs/acre. Minor elements and sulfur were applied in a band near the row at planting.

Early plant growth, total nutrient uptake, yield, grain moisture, and lodging scores were determined.

Results and Discussion

It is often observed that starter or row applied fertilizers result in increased early growth on corn. Much of the research data from the Northern United States points to increased early vigor when planting corn in cool soils from use of starter fertilizer. For many years, it was assumed that because soils were wanner in the Coastal Plain that starter fertilizer was not needed if soil test levels were adequate. However, data from the past several years indicate responses to various N-P combinations when applied to early planted corn regardless of soil test levels (Wright, 1987).

Table 1. Starter placement influence on plant height of no-tilled corn (Quincy).

Placement of Starter (10-34-0)	Earlv Season Height plant (in.) 1984	1985	1986	1987	1988
Control	5.2	5.9	13.9	29.5	21.2
In furrow	6.3	7.8	14.9	41.2	21.8
2"X2"	7.0	---	16.8	45.7	26.2
Surface	6.2	7.8	15.6	41.6	26.2
2" below	6.3	7.6	16.7	48.4	25.9
5" below	5.0	7.0	15.6	40.9	25.4
8" below	4.5	7.1	14.9	38.3	23.5

The efficiency of starter fertilizer on early plant growth may be determined as much by the location of the placement as any other factor. Table 1 data shows that any close placement, even after a broadcast fertilizer application, is better than no starter fertilizer for early season vigor. This early growth may help the plant grow through insect damage, shade weeds and allow for earlier cultivation and sidedressing of N. In each year, the 2x2" placement of starter generally resulted in the most vigorous young growth followed by the surface application and 2" under the seed in the subsoil furrow. Other deeper placement of fertilizer in the subsoil slot generally resulted in a significant stand decrease in each of the 5 years. Plant levels of N and P varied between treatments in each year. Plant samples were collected at 24 inches, 48 inches, tassel, and maturity. Total uptake of nutrients over the years on a per acre basis ranged as follows:

Total Uptake Lb/A for 30,000 plants/A

height	N	P	K
2 4	30-50	4-7	40-80
48"	70-120	9-15	150-200
Tassel	175-210	18-30	230-300
Maturity	250-350	40-55	250-450

Grain moisture near harvest time indicated faster maturity from the 2x2". surface, and 2" below the seed placement. In almost every case, starter fertilizer at any placement resulted in drier grain at harvest or earlier maturity (Table 2).

Table 2. Starter placement influence on grain moisture of no-till corn near harvest (Quincy).

Placement of Starter	Grain H_20 at Harvest 1984	1985	1986	1987	1988
Control	97*	38	36	68	21
In furrow	67	37	35	56	21
2 " X 2 "	44	--	34	37	20
Surface	44	36	35	40	20
2" below seed	66	36	34	36	20
5" below seed	90	37	34	50	21
8" below seed	87	37	36	49	21

*1984 Stalk rot developed prior to maturity.

Lodging was a serious problem 2 out of the 5 years (Table 3). In 1984 stalk rot was a serious problem prior to grain fill. Starter fertilizer placed 2x2" on the surface resulted in earlier maturity which allowed better grain fill than the other treatments and therefore, better yields. Excluding the first year when stalk rot was a problem, all starter treatment yields were higher than the control. On the in-furrow starter treatment had lower yields than the control. This lower yield was due to a reduction in the plant population (about 40%) caused by the close contact of the fertilizer to the germinating seeds. The average yield of all starter treatments was very close

Table 3. Influence of starter fertilizer placement on corn lodging % over 5 years.

	1984	1985	1986	1987	1988
Control	0	4	86	83	I
In furrow	1	6	87	57	20
2 " X 2 "	1	6	82	92	I
Surface	0	6	84	93	I
2" below	I	7	89	89	2
5" below	0	7	90	75	0
8" below	0	10	89	73	0

with the highest average yield coming from the surface application. The 2x2" place likely would have been similar to the surface application and 2" below had we been able to plant the 2x2" treatment at the same time as the other treatments in 1985.

Summary

Starter fertilizer did cause a favorable response in no-till corn as long as it was not placed directly in contact with the seed. Corn grew off faster and matured earlier than corn without starter fertilizer. Lodging in this study was severe which may have been due to the hybrid selected for this study. No differences were noted in lodging with starter fertilizer. Best overall early growth and yield came from starter fertilizer placed on the surface, 2x2" and 2" below the seed on the subsoil shank. Therefore, in no-tillage planting where 2x2" placement is often a problem in dragging residue and interfering with planting that a surface placement to the side of the row or 2" below the seed on the subsoil shank are an acceptable alternative in applying starter fertilizer.

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Corn Production and Profitability as Influenced by Tillage, Winter Cover, and Nitrogen Fertilizer

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Introduction

Reducing soil erosion and increasing profits are two goals of farmers and agronomists alike. Two possible methods for achieving these goals simultaneously are no-till planting and using a winter legume cover crop. This paper compares the corn yields and profits of using different combinations of no-till planting and winter legumes cover crops with those from a conventional tillage system.

Methodology

Thirty six combinations of tillageicover crop treatments and nitrogen (N) fertilizer rates in producing corn *(Zea mays* L.) in Louisiana were tested. The thirty six combinations arose from three tillage options, two cover crops, and six N fertilizer rates. The three tillage options were conventional tillage, no-till with paraplow, and no-till without paraplow. Subterranean clover *(Trifolium subterraneum)* and no planted cover crop (fallow) are the two possible winter covers. Each of the six tillage/cover crop treatments received six rates of nitrogen fertilizer: 0, 36, 71, 107, 143, or 178 pounds of actual N per acre. The experiment occurred at the Ben Hur Farm, Baton Rouge, LA during the 1986 and 1987 growing seasons.

The six tillage/cover crop treatments differed in the type and timing of machinery operations. Table I lists the machinery operations and when they occurred. In Louisiana, conventional tillage for corn consists of three diskings plus some type of subsoiling. In our study, the paraplow was used for subsoiling.

The conventional tillage/fallow treatment began with paraplowing and disking in the fall. The following spring two diskings were made and the corn was planted. For weed control, atrazine (2 lb. a.i./A) and alachlor (3 Ib. a.i./A) were applied soon after planting, followed by mechanical cultivation. A month after planting, liquid nitrogen fertilizer was

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Table 1. The Timing of Machinery Operations for Six Tillage/Cover Crop Treatments in Louisiana.

				Tillage/Cover Crop Treatment					
Operation	Month of operation	Machine size	Tractor size (hp)	Conv. Tillage-fallow	Conv. Tillage-clover	No-till fallow	No-till clover	Paraplow fallow	Paraplow clover
				number of operations					
Paraplow	Nov[a]	4-shank	143	1	1			1	1
Disk	Nov	20 ft	143	1	1				
Drill clover	Nov	12 ft	93		1				
No-till drill clover	Nov	12 ft	93				1		1
Disk	Mar	20 ft	143						
Spray (herbicide)	Mar	30 ft	93						
Plant Corn	Mar	6-row	143						
No-till plant corn	Mar	6-row	143			1	1	1	1
Spray (herbicide)	Mar	30 ft	93	1	1				
Spray (fertilizer)	Apr	30 ft	93	1	1				
Spray (fertilizer and herbicide)	Apr	30 ft	93			1	1	1	1
Combine	Aug	6-row		1	1	1	1	1	1
Truck	Aug	5-ton		0.4	0.4	0.4	0.4	0.4	0.4

a. First year only.

Table 2. Per Acre Corn Production Costs — Six Tillage/Cover Crop Treatments, 1989.

Input	Unit	Price $	Conventional Tillage Fallow	Conventional Tillage Clover	No-till Fallow	No-till Clover	Paraplow Fallow	Paraplow Clover
			$/A					
Corn seed	thou.	0.90	25.20	25.20	25.20	25.20	25.20	25.20
Clover seed	lb	1.50		22.50		22.50		22.50
Inoculant	bag	2.75		0.83		0.83		0.83
Nitrogen	lb	0.21	a	a	a	a	a	a
Phosphate	lb	0.24	9.60	9.60	9.60	9.60	9.60	9.60
Potash	lb	0.14	5.60	5.60	5.60	5.60	5.60	5.60
Paraquat	lb a.i.	20.73			7.77		7.77	
Glyphosate	lb. a.i.	21.25				21.25		21.25
2-4D	lb a.i.	2.73				1.37		1.37
Atrazine	lb a.i.	2.95	4.90	4.90	4.90	4.90	4.90	4.90
Alachlor	lb a.i.	5.50	16.50	16.50	16.50	16.50	16.50	16.50
Linuron	lb a.i.	14.74			14.74	14.74	14.74	14.74
Crop oil	gallon	8.14			1.63	1.63	1.63	1.63
Surfactant	gallon	11.60			5.22	5.22	5.22	5.22
Labor	hour	5.00	8.50	9.50	5.50	6.50	7.50	8.50
Diesel fuel	gallon	0.76	6.23	7.07	2.96	3.80	5.40	6.31
Gasoline	gallon	1.00	1.20	1.20	1.20	1.20	1.20	1.20
Equip. repairs	dollars	1.00	16.89	18.49	13.39	15.37	16.06	18.03
Drying changes	bu	0.18	b	b	b	b	b	b
Interest charges[c]	dollars	0.10	3.55	5.57	4.03	6.65	4.58	7.19
Total operating cost[d]			98.17	126.96	118.24	162.86	125.90	170.57
Machinery costs			32.56	35.60	25.27	29.03	30.73	34.49
Total costs			130.73	162.56	143.51	191.89	156.63	205.06

a. Varies (0, 36, 71, 107, or 178 lb/A.
b. Is a function of corn yield.
c. Excluding any interest charges on nitrogen fertilizer.
d. Excludes nitrogen costs and drying charges.

applied. Corn harvest occurred in August.

The conventional tillage/clover treatment differed from the conventional tillageifallow treatment by the planting of clover in the fall. After the fall disking, clover seed was drilled at a rate of 15 lb./A. The spring diskings were enough to control the clover. For both conventional tillage treatments, paraplowing occurred only once at the beginning of the experiment in the fall of 1985.

The no-tillifallow treatment started with a bum-down application of paraquat (0.375 Ib. a.i./A) followed 7 days later with atrazine (2 lb. a.i/A.) and alachlor (3 lb. a.i./A.) After another 7 day wait, the corn was no-till planted. A month later, liquid nitrogen fertilizer and linuron (1 lb. a.i./A) were applied.

Substituting clover for fallow, the no-tilliclover treatment required the no-till drilling of clover seed at 15 lb/a. Paraquat is not very effective in controlling (killing) subterranean clover (Dabney and Griffin, 1987). To control clover, glyphosate (1 lb a.i/A) and 2-4 D (0.5 lb a.i./A) replaced paraquat. The rest of the inputs did not differ from the no-tillifallow treatment. Note that this study uses the subterranean clover cultivar 'Woogenellup' which is easier to control than 'Mt. Barker' (Dabney and Griffin, 1987).

Both paraplow treatments were simply no-till with paraplowing the first fall. The second year, there were no differences in machinery operations between the paraplow and no-till treatments.

Significant yield differences among the different tillage/cover crop treatments were calculated using paired t-tests. To compare relative profitability of each tillage/cover crop treatment, crop budgets were developed using 1989 Louisiana enterprise budget information (Paxton and Lavergne, 1989; Lavergne and Paxton, 1989). Profits for each tillage/cover crop treatment and N rate combination were calculated using average experiment yields, corn price of $2.84/bu, and the crop budgets from Table 2. Using a 2% real discount rate, profits from the second year were added to the first year's profits. Relative profitability for each tillage/cover crop treatment was then based on total discounted profits. For this analysis profits represented a return to management, risk, and land.

Table 3. Mean Corn Yields (bu/A), Ben Hur Farms, Baton Rouge, LA, 1986-1987

	N Fertilizer Rate (lb/A)						
Tillage/cover crop	0	36	71	107	143	178	Mean
Year	bu/A						
Conv. Tillage/Fallow							
1986	73.7	108.8	114.9	123.8	128.7	138.8	114.8
1987	31.2	65.6	98.5	116.3	132.4	109.2	92.2
Average	52.5	87.2	106.7	120.1	130.6	124.0	103.5
Conv. Tillage/Clover							
1986	120.4	139.4	134.6	115.1	141.2	157.9	134.8
1987	82.5	85.9	101.3	142.1	132.2	102.0	107.7
Average	101.5	112.7	118.0	128.6	136.7	130.0	121.2
No-Till/Fallow							
1986	55.2	94.9	96.3	120.4	123.0	141.7	105.3
1987	36.8	76.0	93.4	82.7	63.1	76.4	71.4
Average	46.0	85.5	94.9	101.6	93.1	109.1	88.3
No-Till/Clover							
1986	90.0	98.6	100.3	109.9	124.4	145.0	111.4
1987	99.9	88.6	106.2	116.9	75.2	93.2	96.7
Average	95.0	93.6	103.3	113.4	99.8	119.1	104.0
Paraplow/Fallow							
1986	64.5	110.0	131.0	117.5	117.4	96.6	106.2
1987	30.1	59.6	89.8	93.5	107.4	87.7	78.0
Average	47.3	84.8	110.4	105.5	112.4	92.2	92.1
Paraplow/Clover							
1986	103.2	125.7	121.5	110.7	115.8	147.5	120.7
1987	91.9	125.1	97.5	99.6	134.9	81.0	105.0
Average	97.6	125.4	109.5	105.2	125.4	114.3	112.9

The difference between average yields that are significant at the 10% confidence level as determined by the paired t-test are:

Conv. tillage/fallow — conv. tillage/clover
Conv. tillage/fallow — no-till/fallow
Conv. tillage/fallow — paraplow/fallow
Conv. tillage/clover — no-till/fallow
Conv. tillage/clover — paraplow/fallow
Conv. tillage/clover — no-till/clovcr
No-till/fallow — no-till/clover
No-till/fallow — paraplow/clovcr
Paraplow/fallow — paraplow/clovcr

Agronomic Results

Table 3 reports the mean corn yields. Conventional tillage produced superior corn yields. The highest two-year average yields for both fallow and clover cover crops occurred with conventional tillage. The top two-year average corn yield of 137 buia occurred using 143 lbiA N following clover as a cover crop. For corn following fallow, the optimal N rate was also 143 lbiA producing a two-year average yield of I3I bu/A. The superiority of conventional tillage yields was also demonstrated by comparing yield differences at each N fertilizer rate within cover crop treatments. For fallow. conventional tillage is superior to no-tilling with and without paraplowing and for clover conventional tillage is superior to no-till without paraplow, all at the 10% confidence level.

Paraplowing increased yields relative to regular no-till for both fallow and clover cover crops. However, the differences were not significant.

Clover as the cover crop treatment produced significantly (at the 10% confidence level) higher average corn yields than fallow for all three tillage treatments. The yield advantage though decreased as the N rate increased. For some years within a tillage treatment, the maximum corn yield following clover occurred at a N rate equal to or greater than that which produced the maximum corn yield following fallow. Thus. clover should not be viewed strictly as a nitrogen fertilizer substitue. It can act as a yield enhancer as well.

In comparing the two years, we find that the yields for all tillage/cover crop treatments were lower the second year. One explanation for the lower yields is the excess rainfall that occurred during tasseling.

Economic Results

Conventional tillageifallow at the 143 lb/A N rate generated the greatest profit over the two years, Table 4. The extra yield from using a clover cover crop for the conventional tillage system was not enough to cover its establishment cost. The price of clover seed, $1.50/1b, is relatively high in 1989 due to supply shortages. Clover seed prices would have to drop to $0.46 lb before it would be economical to plant clover in a conventional tillage system. A price drop of two-thirds is highly unlikely though.

For no-till. paraplowing increased profits. With fallow as the cover crop, paraplowing increased profits over the two year period by almost $40/A. With the clover cover crop, the profit increase was almost $80/A. Paraplowing also decreased optimal N fetilirer levels. For both types of cover crops. optimal N fertilizer for no-till without paraplowing is 178 lb/A. With paraplowing, the optimal N rate decreases to 71 lb/A following fallow and 36 lb/A following clover.

As with conventional tillage, the use of clover as cover crop was uneconomical for both no-till paraplow and regular no-till. Contributing to subterranean clover's uneconomical position was the extra herbicide cost of $20/a required to kill it. If no additional herbicide costs were required, then using clover would become profitable with paraplowing.

Given the high chemical cost of killing subterranean clov-

Table 4. Annual and Total Discounted Profits as a Function of Tillage, Cover Crop and N Rate.

Tillage/Cover Crop	N Fertilizer Rate (lb/A) 0	36	71	107	143	178
			$/A			
Cow. Tillage/Fallow						
Year 1	65.30	149.64	158.28	174.14	179.36	98.64
Year 2	-34.05	47.84	127.77	167.31	202.31	133.01
Discounted total'	31.93	196.52	283.49	338.10	371.62	328.99
Conv. Tillage/Clover						
Year 1	157.71	198.64	178.26	118.58	180.20	217.20
Year 2	70.01	70.02	102.90	204.11	169.95	82.02
Discounted total	226.32	267.26	279.10	318.61	346.75	297.40
No-till/Fallow						
Year 1	3.31	101.11	97.23	153.53	152.63	194.78
Year 2	-45.63	50.84	89.52	53.24	-6.71	21.08
Discounted total	-41.41	150.93	184.96	205.70	146.05	215.44
No-Till/Clover						
Year 1	47.52	62.58	59.51	77.23	107.99	155.19
Year 2	73.85	35.98	75.20	95.85	-22.88	17.40
Discounted total	119.89	97.84	133.21	171.16	85.57	172.24
Paraplow/Fallow						
Year 1	14.94	128.16	176.43	132.70	124.62	61.70
Year 2	-63.45	7.21	79.94	81.97	111.13	51.14
Discounted total	-47.24	135.23	254.77	213.03	233.53	111.82
Paraplow/Clover						
Year 1	69.46	121.50	102.73	66.19	71.95	148.68
Year 2	52.57	133.07	52.06	49.83	135.92	-15.05
Discounted total	120.98	251.91	153.75	115.02	205.15	133.93

1. Discounted total = year 1 + (0.98 x year 2).

er (mowing is not effective) (Dabney and Griffin, 1987), other winter legumes should be evaluated. Hairy vetch *(Vicia villosa)* and crimson clover *(Trifolium incarnatum)* have increased profits for no-till corn grown in Georgia (Franklin, Ott, and Hargrove, 1989). Hairy vetch and crimson clover are easier to control than subterranean clover by either chemicals or mowing (Dabney and Griffin, 1987).

Summary and Conclusions

At least in the short-run, tillage pays. Conventional tillage with paraplow is superior to no-till with or without paraplow. Conventional tillage farmers concerned about soil erosion can plant a legume cover crop like subterranean clover which helps reduce soil erosion with minimal sacrifice in profits. Finally, the cost of killing the legume cover crop can be as important as the cost of planting it when determining legume cover crop profitability.

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Corn Yield Response to Tillage, Hybrids, and Insecticides

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Abstract

Researchers have reported conflicting responwof corn *(Zea mays* L.) to insecticides. This research was conducted to relate insecticides, tillage and corn genotypes to these conflicting responses. Two sets of experiments were conducted. A 3-yr study compared no-tillage (NT) and conventional tillage (CT) (main plots) and four insecticide treatments (split plots) [2.0 lb a.i. Carhofuran A' (CF 2.0), 1.0 lb a.i. Carhofuran a^{-1} (CF 1.0). 2.0 lb a.i. Terhufos A' (TF 2.0), and a untreated control (C)]. A 2-yr study compared six hybrids (main plots) with the previous insecticide treatments (split plots). Grain yield and plant height were measured at harvest. Treatments with CF 2.0 gave higher grain yield in NT, hut TF 2.0 gave equal grain response in CT. Asgrow RX777 yielded 51 bu A^{-1} more grain when treated with TF 2.0 than the C. DeKalb XL71 yielded 45 bu A^{-1} more grain with CF 2.0 than with the C. Since TF and CF were used in the breeding management programs for Asgrow RX777 and DeKalb XL 71, respectively, these interactions suggested that a hybrid would respond better, under farm production conditions, to the insecticide used in it's breeding development management program than an alternative pesticide.

Introduction

Researchers have reported differential and conflicting responses of corn *(Zea mays* L.) to insecticides (5). Environmental factors such as tillage practices, influence both the magnitude and expression of genetic resistance. Other cultural factors such as soil fertility, soil moisture, pesticides, and plant growth regulators affect yield and nutritional quality of host plant tissue appearing to be particularly important in the induction of resistance (13). Genotype populations that were relatively stable in their original environment may become unstable and fluctuate greatly in the stress of a new environment (3, 8).

No-tillage (NT) induces major modifications in ecological conditions in fields, especially the conditions affecting soil fauna (Phillips et al (11). These alterations may enhance, have no affect, or deter the biopotential of soil arthropods. It is generally anticipated that insect infestations will be more severe in NT systems and that insect control will be more difficult than in conventional tillage (CT) corn (9). However, infestations of lesser cornstalk borer *(Elasmopalpus lignosellus* Zeller) were deterred in NT corn cropping systems (2). Both root rot *(Giberellazeae* S.) and Leaf rust *(Piccinia sorghi* S.) affected the absorption and translocation of carbofuran from soils into the plant (12).

The method and timing of pesticide application determine the efficiency of application. Terbufos gave excellent season-long control of greenbugs *(Schizaphis graminum* R.) and increased grain yield when injected into soil. Equivalent rates applied in a band on the soil surface gave poor control (4). Carbofuran used to control northern rootworm *(Diabrotica longicornis* Say) degraded rapidly in some soils, occasionally failing in other soils (6,7). A tillage-corn genotypes study with 60 hybrids showed no differential response of these hybrids to tillage (NT vs CT) (10).

Hybrid selection is usually related to high yield and may be carried out under high fertility, irrigation, and good pest control. It is suggested that hybrids selected in this manner may not perform well in other environments (low fertility, nonirrgation, and other pesticides) (1)

The objectives of this research were to relate insecticides to tillage and corn genotypes, and to better understand the reported conflicting responses of corn to insecticides.

Materials and Methods

This research was conducted in the north-central Florida region on Hernando LFS (Typic Hapludalf) soil. A randomized complete block design was used.

Tillage/Pesticide Study

In this 3-yr study (1981, 1982, 1983) the response of

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DeKalb XL71 corn hybrid to insecticides under two tillage management conditions was evaluated. No-tillage plus in-row subsoil versus CT plus in-row subsoil were whole plots with four replications and three insecticide treatments and a control as the split plots [1.0 lb a.i. Carbofuran A^{-1} (CF 1.0) 2.09 lb a.i. Carbofuran A^{1} (CF 2.0), 2.0 lb a.i. Terbufos $^{-1}$ (TF 2.0) and a untreated control (C)]. Split plots were 10 feet wide, and 30 feet long. There were four rows 30 in. apart. Plots were kept under monocrop corn for 6-yr, 3-yr prior to the implementation of the pesticide treatments, and during the 3-yr experiment. DeKalb XL71 was planted at 36,400 seed A^{-1} 27 Feb. 1981, 8 Mar. 1982 and 10 Mar. 1981. A Brown Harden in-row subsoil NT planter was used in NT and CT (prepared with an off-set Harrow And Rototiller). The pesticide treatments were applied in 6 in. bands over the row at planting. Complete fertilizer including N, P, K, S, Mg, Fe, Cu, B, Zn and Mn was broadcast prior to planting based on soil test and plant need. Preplant broadcast fertilization include 180 lb ammonium nitrate (NO_3), and 200 lb KMAG A^{-1}. Also, Ammonium nitrate was sidedressed at a rate of 150 lb A^{1} when plants were 10 in. tall. Weed control was done 10 days prior to planting with Paraquat plus X77 surfactant. When corn was about 6 in. tall a post-broadcast application over the top was done with Atrazine (2.0 lb a.i. A^{-1} and 1 quart crop oil A^{-1}).

Collected data consisted of plant height at the soft dough state of grain formation, and corn grain yield at harvest. Statistical analyses were performed using split plot ANOVA on a TRS-80 model III microcomputer. Means were tested at the 0.05 probability level.

Genotype/Pesticide Experiments

A three-location study with six commercial hybrids was evaluated for yield as affected by pesticide treatment during 1982 and 1983. Locations were in Alachua county, FL in 1982 and in Levy county, FL in 1983. The three locations had similar cropping histories, of continuous double cropped NT corn followed by soybean *(Glycine max* L.).

The hybrids evaluated were the following; Asgrow RX777, DeKalb XL 71, Funks G4507A, Coker 19, Pioneer 3320, and Gold Kist 748. Hybrids were whole plots with 4 replications. The same insecticides and rates used in the tillage/pesticide study were split plots with the same plot size and cultural practices. Data collection, and statistical analyses were handled in the same manner.

Results and Discussion

Tillage/Pesticide Study

Interactions between tillage and pesticide treatments were shown for grain yield, and plant height (Tables 1, and 2). Grain yield for NT, CF 2.0 was significantly greater than other treatments at the 0.05 probability level. All pesticide treatments gave higher grain yield than the Control (Table 1).

There were no difference among pesticide treatments with CT. No-tillage grain yield was greater than CT for CF 1.0. Terbufos 2.0 did not show any differences between tillage treatments. With no pesticide NT grain yield was higher than CT.

The tallest plants occurred under NT condition at the highest rate of CF 2.0. The CF 1.0, TF 2.0, and C did not differ in NT (Table 2). Under CT both CF 2.0 and CF 10 gave the tallest plants. The TF 2.0 treatment had shorter plants than the Carbofuran treatments. The C had the shortest plants in CT. Among the pesticide treatments, tillage treatments were different only for the highest rate of Carbofuran, and was in favor of NT (Table 2).

Table 1. Corn graln yield response to tillage and pesticides (three year average).

Pesticide	Rate	Tillage[3/] NT	CT		Avg
	lb a.i. A'		bu A-[1]		
Carbofuran	2.0	188 a	173 a	*	181
Carbofuran	1.0	159 b	172 a	*	166
Terbufos	2.0	162 b	165 a	NS	164
Control	0.0	146 c	129 b	*	138
Avg		164	160		

a,b,c, = within columns among pesticides.
* = different at .05 P in rows between tillage.
NS = nonsignificant.
[3] NT = No-tillage, CT= Conventional Tillage.

Table 2. Corn plant height response to tillage and pesticides (two year average).

Pesticide	Rate	Tillage NT	CT		Avg
	lb a.i. A^{-1}		feet		
Carbofuran	2.0	8.7 a	8.3 a	*	8.5
Carbofuran	1.0	8.1 b	8.3 a	NS	8.2
Terbufos	2.0	8.1 b	8.0 b	NS	8.0
Control	0.0	7.9 b	7.7 c	NS	7.8
Avg		8.2	8.1		

a,b,c, = within columns among pesticides.
* = different at .05 P in rows between tillage.
NS = nonsignificant.

Genotype/Pesticide Study

Interactions were shown between genotype and pesticide treatments under NT conditions for both grain yield and plant height (Tables 3, and 4). Asgrow RX777 attained the highest grain yield (167 bu A^{-1}) using TF 2.0. All hybrids obtained highest grain yield with CF 2.0. Coker 19 responded equally to TF and CF. Pioneer 3320 responded equally to the two CF rates (Table 3). Grain yields were compared across hybrids within an individual pesticide treatment (Table 3) and showed that for CF 2.0 DeKalb XL71 and Gold Kist 748 gave the highest grain yield. However when CF 1.0 was used Pioneer 3320 and Gold Kist 748 gave the highest grain yield. Terbufos seemed to favor Asgrow RX777 grain yield over the others. When the hybrids were placed in a untreated environment Pioneer 3320 gave the greatest grain yield.

In general the tallest plants occurred with CF 2.0 (8.4 feet). The exception was DeKalb XL71 with the tallest plants from TF 2.0 (8.1 feet). The C gave the shortest plants. The plant height response among hybrids within an individual

Table 3. Corn hybrid grain yield in relation to pesticides across tillage treatment and locations.

	Insecticide Treatment[1]				
	Carbofuran		Terbufos	Control	Avg
Rate	2.0	1.0	2.0	0.0	
Hybrid	bu A⁻¹ [2]				
Asgrow RX777	154 v b	146 w c	167 u a	116 vw d	146
DeKalb xL71	164u a	146 w b	143 v b	119 vw c	143
Coker 19	146 w a	151 vw a	148 v a	119 vw b	141
Gold Kist 748	165u a	156uv b	134 w c	122 v d	144
Funks G4507A	143 w a	132 x b	126 w c	110 w d	128
Pioneer 3320	156 v a	161u a	142 v b	145u b	151
Avg	155	149	143	122	

'Insecticide rates expressed as lb a.i. A1. 'a,b,c = within rows of pesticides, and u,v,w,x = within columns, values not followed by the same letter are significantly different at the 0.05 level of probability.

Table 4. Corn hybrid plant height in relation to pesticides across tillage treatment and location.

	Insecticide Treatment[1]				
	Carbofuran		Terbufos	Control	**Avg**
Rate	0.0	1.0	2.0	0.0	
Hybrid	feet				
Asgrow RX777	8.2 v a	7.7 y c	7.9 w b	7.1 w d	7.7
DeKalb XL71	7.9 w b	7.8 x c	8.1 u a	7.7 uv c	7.9
Coker 19	8.2 v a	7.5 z c	7.7 x b	6.9 x d	7.6
Gold Kist 748	8.4 u a	8.2 u b	8.0 vw c	7.8 u d	8.1
Funks G4507A	8.0 w a	7.9 w a	7.6 y b	7.1 w b	7.7
Pioneer 3320	8.3 u a	8.1 v b	7.8 x c	7.7 v d	8.0
Avg	8.2	7.9	7.9	7.4	

pesticide treatment is shown in table 4. This comparison showed that CF rates gave the tallest plants for Gold Kist 748. DeKalb XL71 plant height was increased by TF 2.0. Gold Kist 748 and DeKalb XL71 were also the tallest plants when placed in a untreated environment (C).

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Yield and Ear Leaf Nitrogen Status in No-Tillage Second Crop Temperate and Tropical Corn

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Abstract

Fertilization and management of second crop corn *(Zea mays* L.) should differ from spring planted corn and need to be investigated in order to achieve optimum production. This study was conducted to observe the effects of sidedressed N and K on whole plant and grain yields of three second crop corn cultivars. The cultivars 'Pioneer 3320' (temperate hybrid), 'Pioneer X304C' (tropical hybrid), and 'FLOPUP' (Florida open pollinated, upright ear experimental) were planted at two locations in August 1987 near Gainesville,Florida on Arenic and Grossarenic Paleudults. At both locations four N rates (0,30,60, and 120 lb NA^{-1}) as subplot and two K-Mg (K_2SO_4:$MgSO_4$) rates (0 and 120 lb A^{-1}) as sub-sub-plot treatments were imposed in **a** split-split-plot field experiment with cultivars as main plot treatments in a randomized complete block design. Whole plant and grain yields at harvest were affected by cultivar and sidedressed Nand K-Mg rates at both locations. Cultivar and **N** and K-Mg rates affected ear leaf N concentration differently at each location. Maximum whole plant yields (13.9 and 14.5 ton A^{-1} at 35% moisture) were obtained from FLOPUP with 60 and 120 lb sidedressed **N** A^{-1} at location 1 and 2, respectively. Maximum grain yield (80 hu A')was obtained from FLOPUP with 120 lb sidedressed N A^{-1} and application of K-Mg.

Introduction

A second crop of corn *(Zea mays* L.) planted in late summer may provide Florida's dairy and beef cattle farmers with needed high quality forage. The late summer growing season is characterized by high rainfall, shortening day-length, reduced solar intensities, and decreasing mean daily temperatures. Reductions in yield caused by reduced day-length and solar intensity may be partially offset by the increased grain filling period resulting from lower mean temperatures. Photoperiod has been reported to have a greater effect than temperature on determination of plant leaf number and days to tassel initiation (Russell and Stuber, 1983). Brakke et al (1983) reported that to maximize corn yields, specific corn cultivars for specific environments and cropping systems need to be developed. Selection and breeding of corn cultivars which perform well in the late summer environment have been reported by Gallaher and others (Bustillo and Gallaher, 1988; Gallaher, 1986). The objective of this experiment was to study the yield response of three second crop corn cultivars grown under late summer conditions to sidedressed N and K-Mg (K_2S0_4:$MgSO_4$) fertilization.

Materials and Methods

This experiment was part of a larger field study investigating the growth and yield of temperate and tropical corn cultivars shown in late summer (Overman and Gallaher, 1989).Soils at both experimental sites were associations of Arenic and Grossarenic Paleudults (Soil survey Staff 1984). Three corn cultivars, 'Pioneer 3320' (temperate hybrid). 'Pioneer X304C' (tropical hybrid) and 'FLOPUP' (Florida open pollinated upright ear experimental line) were planted 8 August 1988 with a Brown-Harden no-tillage planter at a rate of 60,700 seed A^{-1} and thinned to 34,000 plants A^{-1} two weeks after emergence. Anhydrous ammonia at 89 lbs N A^{-1} was injected 10 inches below the row at planting. Ammonium nitrate (67 lbs N A^{-1}), muriate of potash (100 lb K A^{-1}), triple super phosphate (21 lb P A^{-1}) sulfate of potash magnesia (11 lb Mg A^{-1} 22 lb K A^{-1} 23 lb S A^{-1}) and Perk (25 lb containing the following percentages of soluble elements: 5% S, 5% Mg, 0.02% B, 0.50% Cu, 9% Fe, 2% Mn. 0.003%Mo, and 1% Zn) were surface broadcast immediately after planting. Irrigation water was applied by overhead sprinkler to insure at least 1 inch per four to seven days until early tassel, 1.5 inches per four days during early seed fill and l inch per four to seven days during late seed fill.

The herbicide Dual (Metolachlor: 2-chlora-N-(2-ethyl-6-methyIpheyl)-N-(2-methoxy-lmethylethyl) acetamide) was applied pre-emergence at 2 lb a.i. A'. Counter (Terbufos: S-(1-1-Dimethylethyl) thio)methyl)0,0-diethyl phosphorodithionate) was applied in bands over the row before emergence at a rate of 2 lb a.i. A^{-1} Gramoxone (Paraquat: 1,1'-Dimethyl-4,4:-bipyridium ion) at 0.37 Ib a.i. A^{-1} with a non-ionic surfactant (X77) was spot applied at knee-high stage. Two applications of Lannate (Methomyl S-Methyl-N-((methylcarbomoyl) oxy) thioacetimiddte) at 0.22 lb a.i. A^{-1} were sprayed into the whorl at 30 and 45 days after

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planting (DAP) to control fall armyworm *(Spodoptera frugiperda* L.)

Approximately 9 inches of rainfall occurred over a one week period in early September with over 3 inches occurring on 4 September 1988. Uniform chlorosis with some plants exhibiting both N and K deficiency symptoms was observed one week later in all three cultivars. It was strongly suspected that both N and K and possible S and Mg fertilizer applied earlier had leached from the root zone. Soil samples were taken at both locations to determine pH, organic C and Mehlich 1 extractable P, K, Ca, and Mg. Soil test means for location 1 were: pH of 6.4, 1.13% organic C, and P, K, Ca, and Mg amounts of 148,103,838 and 106 lb A^{-1}, respectively. On 12 September four N rates (0, 30, 60, and 120 lb N A^{-1}) and two K-Mg (K_2SO_4:$MgSO_4$) rates (0 and 120 lb A) were imposed as subplot and sub-subplot treatments, respectively, across all three cultivars at both locations. Ear leaf samples were collected at mid-silking (66 DAP) for N concentration determination by Micro-Kjeldahl technique (Gallaher et al, 1975; Gallaher et al, 1976). Whole plant and grain yields were determined at harvest and corrected to 15.5 and 35% moisture for grain and whole plant samples, respectively.

Results and Discussion

Grain and whole plant yields at both locations were significantly affected by the single effects of cultivar and N rate. The three way interaction of cultivar x N rate x K-Mg level was significant at location 2 and highly significant at location 1. Grain and whole plant yield means from locations 1 and 2 are presented in Tables 1 and 2, respectively. At both locations grain and whole plant yields of Pioneer 3320 did not show response to added N or K-Mg. At location I Pioneer X304C grain and whole plant yields responded to N rate when K-Mg was added. At location 2 grain and whole plant yields of Pioneer X304C showed less response to N rate and a slight response to K-Mg at the 30 lb N A^{-1} rate. Grain and whole plant yields of FLOPUP at location 1 showed a response to K-Mg application at 0, 30, and 60 lb N A^{-1} rates. At location 2 FLOPUP grain and whole plant yields exhibited a negative response to K-Mg addition at the 60 lb N A^{-1} rate and no response at other rates.

Ear leaf N concentration means for location 1 are presented in Table 3. Ear leaf N concentration was significantly affected by N rate at both locations and by K-Mg at location 2. At N rates of 0 and 30 lb A^{-1} FLOPUP was observed to have higher ear leaf N concentrations. At 60 and 120 lb N A^{-1} rates no differences among cultivars were noted. Within cultivars at location I little response to sidedressed N by Pioneer 3320 in ear leaf N concentration was noticed.

Ear leaf concentration means for location 2 are presented in Table 4. A positive increase in ear leaf N concentration occurred with K-Mg addition. Nitrogen application produced significantly higher ear leaf N concentrations than no application; however no differences among the three rates (30, 60, and 120 lb N A^{-1}) were noted.

According to Jones (1974) the sufficiency range for N in

Table 1. Grain and whole plant yields of corn cultivars as affected by sidedressed N rate and K-Mg for location 1.

Nitrogen	Pioneer 3320 K-Mg +	Pioneer 3320 K-Mg	Pioneer X304C K-Mg +	Pioneer X304C K-Mg	FLOPUP K-Mg +	FLOPUP K-Mg
Grain Yield						
lb A^{-1}			bu A^{-1}			
0	38	36	44	49	48	32
30	49	42	*64*	60	57	46
60	44	36	69	61	59	68
I20	35	41	55	53	41	55

LSD (0.05) 9 to compare K-Mg means for fixed N and cultivar.
LSD (0.05) 13 to compare N means for fixed cultivar and K-Mg.
LSD (0.05) 17 to compare cultivar means at fixed N and K-Mg.

Nitrogen	Pioneer 3320 K-Mg +	Pioneer 3320 K-Mg	Pioneer X304C K-Mg +	Pioneer X304C K-Mg	FLOPUP K-Mg +	FLOPUP K-Mg
Whole Plant Yield:						
lb A^{-1}			ton A^{-1}			
0	7.1	7.7	8.0	8.9	10.1	7.0
30	9.4	8.3	11.4	10.8	12.0	9.5
60	8.1	7.1	12.0	11.0	11.9	13.9
I20	7.4	8.6	9.6	9.2	9.9	11.2

LSD (0.05) 1.9 to compare K level means for fixed N and cultivar
LSD (0.05) 2.5 to compare N means for fixed cultivar and K-Mg.
LSD (0.05) 3.4 to compare cultivar means to fixed N and K-Mg.

Grain yield of No. 2 grain expressed at 15.5% moisture.
Whole plant yield expressed at 35% moisture.
K-Mg K_2SO_4:$MgSO_4$) rate was 120 lb A_{-1}.

Table 2. Grain and whole plant yields of corn cultivars as affected by sidedressed N rate and K-Mg for location 2.

Nitrogen	Pioneer 3320 K-Mg +	Pioneer 3320 K-Mg -	Pioneer X304C K-Mg +	Pioneer X304C K-Mg	FLOPUP K-Mg +	FLOPUP K-Mg
Grain Yield						
lb A^{-1}			bu A^{-1}			
0	29	31	59	67	59	53
30	38	37	74	57	57	58
60	33	36	77	73	54	72
120	40	38	68	76	80	73

LSD (0.05) 14 to compare K-Mg means for fixed N and cultivar.
LSD (0.05) 17 to compare N means for fixed cultivar and K-Mg.
LSD (0.05) 34 to compare cultivar means at fixed N and K-Mg.

Nitrogen	Pioneer 3320 K-Mg +	Pioneer 3320 K-Mg -	Pioneer X304C K-Mg +	Pioneer X304C K-Mg	FLOPUP K-Mg +	FLOPUP K-Mg
Whole Plant Yield:						
lb A^{-1}			ton A^{-1}			
0	6.9	7.0	10.4	10.9	11.6	10.0
30	8.0	7.8	12.9	9.6	11.4	11.1
60	7.0	7.6	13.0	12.1	10.0	13.0
120	8.3	7.6	11.7	12.6	14.5	13.1

LSD(0.05) 2.6 to compare K level means for fixed N and cultivar.
LSD(0.05) 3.0 to compare N means for fixed cultivar and K-Mg.
LSD(0.05) 3.1 to compare cultivar means to fixed N and K-Mg.

Grain yield of No. 2 grain expressed at 15.5% moisture.
Whole plant yield expressed at 35% moisture.
K-Mg (K_2SO_4:$MgSO_4$) rate was 120 lb A^{-1}.

Table 3. Ear leaf N concentration means by N rate and cultivar for location 1.

	Cultivar		
Nitrogen	Pioneer 3320	Pioneer X304C	FLOPUP
lb A^{-1}		%N	
0	2.67	2.34	2.56
30	2.61	2.56	2.85
60	2.89	2.86	3.02
120	2.86	2.88	2.82

LSD(0.05) 0.12 to compare N rate means for a fixed cultivar.
LSD(0.05) 0.16 to compare cultivar means for a fixed N rate.

Table **4.** Ear leaf **N** concentration means by N rate and K-Mg level for location 2.

	K-Mg		
Nitrogen		+	Mean
lb A^{-1}		**% N**	
0	2.58	***2.64***	2.61
30	2.81	2.85	2.83
60	2.82	2.92	2.87
120	2.86	**3.05**	2.96
Mean	2.17	2.87	2.82

LSD(0.05) 0.10 compare K-Mg rate means.
LSD(0.05) 0.21 to compare among N rate means

K-Mg (K_2SO_4:$MgSO_4$) rates of 0 and 120 lb A^{-1}.

the ear leaf of corn sampled at tasseling and before the silks turn brown would be 2.75 to 3.20%. Values for the three cultivars fell within this range from the application of 60 lb N A^{-1} for Pioneer 3320 and Pioneer X304C and 30 N A^{-1} for FLOPUP at location 1 and no K-Mg was needed (Table **3.**). At location 2 all cultivars responded similarly and required 30 lb N A^{-1} and K-Mg to have leaf N values that fell within the sufficiency range.

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Growth and Partitioning of Dry Matter Between Temperate and Tropical Corn

D.L. Overman and R.N. Gallaher[1]

Abstract

The objective of this research was to determine corn (Zea mays L.) dry matter (DM) and grain yield differences among a temperate hybrid (Pioneer 3320), a tropical hybrid (Pioneer X304C) and 'FLOPUP' (FI. open pollinated upright ear experimental of the 8th selection), as affected by cultivar and planting date. The experiment was conducted at two locations at Green Acres Agronomy Farm near Gainesville, FI., in 1988. There were three planting dates -March, May, and August. Twelve harvest samplings for each crop were made beginning at 35 days after planting (DAP) and ending at 150 DAP. In the March planting, total plant DM reached a maximum about 112 to 120 DAP. Maximum whole plant DM was 9.8, 8.5, and 8.3 tons A^{-1} for Pioneer 3320, Pioneer X304C and FLOPUP, respectively. Grain yield was 207, 150, and 114 bu A^{-1} for Pioneer 3320, Pioneer X304C, and FLOPUP, respectively. Grain yield was 93, 114, and 86 A^{-1} for Pioneer 3320, Pioneer X304C, and FLOPUP, respectively. For the August planting, total plant DM reached a maximum about 88 lo 112 DAP. Maximum whole plant DM was 3.3, 3.8, and 4.6 tons A^{-1} for Pioneer 3320, Pioneer, X304C, and FLOPUP, respectively. Grain yields were 64, 78, and 78 A^{-1} for Pioneer 3320, Pioneer X304C, and FLOPUP, respectively.

Introduction

In recent years some effort has been made to evaluate and develop genotypes and to determine the proper management required to grow corn (*Zea mays* L.) in the late spring or fall of the year (Baldwin and Gallaher, 1984; Bustillo and Gallaher, 1988; Gallaher and Horner, 1983; Gallaher, 1986). If this possibility were to exist, spring corn farmers and winter

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wheat (*Triticum aestivum* L.) fanners could grow an additional crop of corn succeeding these crops in the subtropical climate of the southeastern U.S.(Nelson et al., 1977). Research regarding planting dates, row spacing and plant populations is also relevant to an understanding of growing double-crop corn and the environmental factors involved (Eckert, 1984; Imholte and Carter, 1987; Wright et al., 1987).

Genetics and management for top corn yield is a fall crop may be quite different from that of a spring crop. It is unlikely that fall planted corn will partition dry matter in vegetative and reproductive tissues in the same manner as spring planted corn. For optimiizing dry matter and grain yield, genetic requirements of fall planted corn is also likely to be different from spring planted corn.

The objective of this research was to determine corn dry matter and grain yield differences among a temperate hybrid, a tropical hybrid, and an open-pollinated experimental cultivar, as affected by planting date and cultivar.

Materials and Methods

The experiment was conducted at two locations with two different cropping histories at the Green Acres Agronomy Farm near Gainesville, Florida in 1988. The experimental sites were dominated by Arenic and Grossarenic Paleudult soils (Soil Survey Staff, 1984). 'Pioneer 3320' (temperate corn hybrid), 'Pioneer X304C' (tropical corn hybrid) and FLOPUP (Florida open-pollinated upright ear experimental of the 8th selection) were the three cultivars used.

Conventional tillage seedbeds were prepared for planting each crop with a Brown-Harden in-row subsoil no-tillage planter. Plots were planted at about 60,700 seed A^{-1} and thinned to the desired population of 34,400 plants A^{-1} two weeks after seedling emergence. Anhydrous ammonia (89 N A^{-1} was injected 10 inches under the row during the planting operation. Ammonium nitrate (67 lb N A^{-1} Muriate of potash (100 lb K A^{-1} Triple super phosphate (21 lb P A^{-1} Sulfate of potash magnesia (11 lb Mg A 22 lb K A^{-1} 23 lb S A^{-1} and Perk (25 lb A^{-1} containing the following percentage soluble elements: 5% S, 5% Mg, 0.02% B, 0.50% Cu, 9% Fe, 2% Mn, 0.003% Mo., and 1% Zn) was broadcast immediately after planting. Sidedress applications of ammonium nitrate (31 lb N A^{-1} each time) were applied at 40 and 60 days after planting.

Water was applied by overhead sprinkler in addition to rainfall to insure at least 1 inch per four to seven days until early tassel, increasing to a maximum of 1.5 inches per four days during rapid seed fill and decreasing to 1 inch per four to seven days during late seed fill. Counter [Terbufos: S-(((1, 1-Dimethylethyl)thio) methyl)0,0-diethly phosphorodithionate] at 2 lb ai A^{-1} was banded over the row before emergence. The August planted corn received two applications of lannate 1Methomyl:S-Methy1-N-((methyl carbamoyl)oxy) thioacetimedate] (one pint product A-1each time) sprayed directly in the whorl at 30 and 45 days after planting (DAP)to control fall army worm. Dual [Metolachlor:2-chloro-N-(2-ethly-6-methylphenyl)-N-(2-methoxy-1methylethyl) acetamide] at 2 lb ai A^{-1} was sprayed pre-emergence each time. Post direct applications of gramoxone [Paraquat: 1,1'-DimethyI-4,4'-bipyridinium ion] plus X77 non-toxic surfactant were applied as needed after corn reached about 30 inches height. Additional weed control was by hand.

Results and Discussion

The tropical cultivars (Pioneer X304C and FLOPUP) were expected to produce better in the late spring and summer plantings than the temperate cultivar (Pioneer 3320). which would be expected to produce better in the early spring plantings. This is shown in Table 1. Dry matter yield for Pioneer 3320 in the March planting was approximately 17% greater than the yields of Pioneer X304C and FLOPUP. The peak accumulation was about I12 to 120 DAP, with Pioneer 3320 reaching the peak earlier. In the May planting, the DM yield of Pioneer X304C was approximately 38% and 29% greater than the yields of Pioneer 3320 and FLOPUP, respectively. The maximum DM accumulation occurred about 84 to 100 DAP; Pioneer 3320 reached the maximum about two weeks earlier than the other cultivars. Dry matter yield for FLOPUP in the August crop was approximately 39% and 21% greater than the yields of Pioneer 3320 and Pioneer X304C, respectively. The maximum DM accumulation was about 88 to 112 DAP; Pioneer 3320 reached maximum production about one week before Pioneer X304C, and two weeks before FLOPUP. The tropical cultivars produced more dry matter in the May and August plantings than the temperate hybrid, as would be expected.

Grain yield for the three crops in shown in Table 1. Pioneer 3320 had the highest grain yield in the March planting, 207 bu A^{-1}, which is approximately 39% and 82% greater than the yield of Pioneer X304C and FLOPUP, respectively. In the May planting, Pioneer X304C had the highest grain yield, I14 bu A^{-1} approximately 23% and 33% greater than the yield of Pioneer 3320 and FLOPUP, respectively. For the August crop, FLOPUP and Pioneer X304C each had maximum grain yields of 78 bu A^{-1} approximately 22% greater than the yield for Pioneer 3320.

Table 1. Maximum whole plant dry matter and grain yield by three corn cultivars affected by planting date.

Cultivar	Month of Planting March	May	August
	Ton A^{-1}		
Pioneer 3320	9.9	5.5	3.3
Pioneer X304C	8.5	7.6	3.8
FLOPUP	8.3	5.9	4.6
Average	8.9	6.3	3.9
	Bu A^{-1}		
Pioneer 3320	207	93	64
Pioneer X304C	150	114	78
FLOPUP	114	86	78
Average	157	98	73

The rate of total DM loss (from the time of maximum yield until the end of the season) is shown in Table 2. This illustrates the importance of harvesting in a timely manner.

Table 2. Rate of total dry matter loss following peak near black layer formation.

Planting month	Pioneer 3320	Cultivar Pioneer X304C	FLOPUP
		Bu A^{-1}	
March	214	151	160
May	71	80	80
August	9	< 9	53

The rate of deterioration is greater in the March and May plantings when there are higher temperatures and rainfall than in the fall. Information was not available that had compared planting dates from early spring to late summer. Research on the effect of planting dates, photoperiod, and temperature include Imholte and Carter (1987), and Warrington and Kansmasu (1983).

Spring corn grain-fill occurs during increasing day lengths and temperatures. The May planted corn developed and reproduced during the maximum day length and temperatures. There are potential problems for the August crop due to decreasing day length, temperature, and natural rainfall in Florida, as well as increased pest problems (Bustillo and Gallaher, 1988; Gallaher and Homer, 1983).

Summary

Temperate hybrids such as Pioneer 3320 that were developed for early planting do not perform well when planted in late summer. In total DM and grain yield, Pioneer 3320 produced the highest yields in the March planting. The highest yields in the May and August plantings were produced by Pioneer X304C and FLOPUP, respectively. The rate of total DM loss or deterioration was greater in the early planting. Genetic potential exists for reasonable corn yields in mid to late summer plantings.

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Dry Matter Partitioning in No-Tillage Tropical Corn in Florida

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Abstract

The long frost-free period in Florida could allow numerous multiple croping alternatives to farmers. This study was conducted 1) to determine the best plant population for highest yield of tropical open pollenated corn (Zea *mays* L.) when planted as a second crop in the late summer in north central Florida and 2) to determine the partitioning of dry matter among the corn parts. Six populations were studied in increments of 4,000 plants A ' and ranged from 12,000 to 32,000 plants A^{-1}. The study was conducted at two locations on the Green Acres Agronomy Farm on an Arredondo loamy sand (Grossarenic Paleudult) in 1987. Treatments were replicated six times in a randomized complete block design. Corn was harvested at black layer formation. Plants were separated into leaves, stalks, shucks, cobs, and grain and dried at 70 C for estimation of dry matter production. Maximum yield was obtained at the 32,000 plants A^{-1} population.

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INTRODUCTION

Florida is on the border line of the 30 degree latitude, it is not a large corn *(Zea mays* L.) producer and its corn yield average is about 62 bu A^{-1} On the other hand, the dairy and beef cattle farmers of north Florida, have a need of high quality forage in the fall and winter months. At present their choices of a summer annual forage crop that will grow in the fall are limited to crop species such as forage sorghum *(Sorghum bicolor* L. Moench), grain sorghum *(Sorghum bicolor* L. Moench), sudangrass *(Sorghum sudanese)* and corn.

Corn is the most commonly ensiled crop in the USA, preferred for its better quality and yield of digestible nutrients over the other choices. Corn grain is over 90% digestible and corn silage is about 70%. while sudangrass silage is about 46% (Wright et al., 1983). However, there had been limited success with fall grown corn due to the lack of adapted genotypes which can withstand the environmental stress.

During the past 6-yr, field research has been conducted to develop an open pollenated variety selected for the hot humid summer and cool fall climate of north Florida. This material originated in the hot humid tropics of Costa Rica and was allowed to cross with selected tropical and temperate hybrids in Florida. The experimental population FLOPUP (Florida open pollenated upright ear) has been selected for testing. FLOPUP has been developed for planting in August and harvest in the late fall in north and central Florida. However, the low fall temperatures and short day-length, during the critical stage from silking to maturity, may severely reduce dry matter accumulation and final grain yield. Several authors (Breuer et al., 1976; Hunter et al., 1977), have established that many corn genotypes are photoperiodically sensitive. Roberts and Struckmeyer (1938) were among the first to report the effects of temperature on the response of corn to photoperiod. Corn genotypes also differ in their response to temperature (Breuer et al., 1976).

Numerous research studies have dealt with determining the optimum plant population for a given hybrid under a certain environment. The majority of results show that optimum plant population may vary from about 16,000 to over 40,000 plant A^{-1} (Larson and Hanway, 1977). In Georgia, optimum plant populations for two hybrids over a 2-yr period varied from 17,000 to 41,000 plants A^{-1} under irrigated conditions (Brown et al., 1970).

The objectives of this research were: 1) to determine the best plant population for highest yield of FLOPUP when planted as a second crop in the late summer in north central Florida, and 2) to determine the distribution of dry matter among the corn parts.

Materials and Methods

FLOPUP (Florida open pollenated upright ear experimental population of the 7th cycle of mass selection) was planted in early August, 1987 at the Green Acres Agronomy Farm, near Gainesville. The randomized complete block design had six replications with six plant populations as treatments of four rows, 20 ft long and 2.5 ft wide. The population treatments were 12,000, 16,000, 20,000, 24,000, 28,000 and 32,000 plants A^{-1}.

Planting was done with a Brown-Harden in-row-subsoil no-tillage planter. Fertilizer was applied according to soil test. About 40,000 seed A^{-1} were planted and the populations were fixed by thinning when corn reached an average of about 4 in. in height.

Preemergence herbicides such as Atrazine (2 lb a.i. A^{-1}), Sencor (Metribuzin) (0.4 lb A^{-1}), Lasso (Alachlor) (2 lb a.i. A^{-1}), and Paraquat (0.4 lb a.i. A^{-1} plus recommended surfactant, were sprayed over the plots. It was necessary to apply paraquat as postdirected to control weed problems in certain areas. Small areas of weeds were also controlled mechanically by hand.

Irrigation was applied by overhead sprinkler and guns as needed, depending on natural rainfall. The insects were controlled as needed by use of Lannate (Methomy) (2 lb a.i. A^{-1}) and granulated Furadan (Carbofuran) (2 lb a.i. A^{-1}). Lannate was sprayed over the plants and furadan was applied in the row at planting.

At black layer formation on the grain, data was collected on whole plant yield, grain yield and grain shelling percent, to determine the effects of plant population on these factors and the best population required to optimize yield under the prevailing conditions. Silage yield was estimated from dry matter data.

Statistical analysis was done using a Tandy model 1000 SX microcomputer using the MSTAT program for the ANOVA of a randomized complete block design and mean separation by Fisher protected (LSD) test. Regression analysis of the dependent variables dry matter of grain and whole plant yield, were tested against the independent variable plant population.

Results and Discussion

In general all yield variables responded to increased plant populations (Table I). For the lowest treatment of 12,000 plants A^{-1} to 32,000 plants A~'the maximum treatment, the grain yield obtained went from 24 bu A^{-1}, 40 bu A^{-1}, respectively. This represented a proportional increase of up to 60% over the lowest yield for the lowest population treatment. Theseyields were low compared with yields of tropical hybrids, such as Pioneer brand X304C, with a yield of 124 bu A^{-1} (Gallaher and Baldwin, 1985), grown at the same location during a previous year but planted in March rather than August.

Linear regression was positive for grain and plant dry matter yield as a function of plant population, with an equation of y grain dry matter yield (Ib A^{-1}) 790 0.034X for grain, and y dry matter yield (lb A^{-1}) 2315 0.144X for plant dry

Table 1. Yield variable of August planted corn affected by plant population (Two location average in 1987 at Gainesville, FL.)

Density	Grain		Cob	Shuck	Shelling
plants A^{-1}	Bu A^{-1}	............Ton DM A^{-1}	....		5
12,000	24 c	0.57 c	0.18 b	0.29 c	76a
16,000	27 c	0.64 c	0.21 b	0.36 b	75a
20,000	35ab	0.84ab	0.27a	0.41ab	76a
24,000	32 b	0.77 b	0.25a	0.40ab	75a
28,000	36ab	0.85ab	0.28a	0.43ab	76a
32,000	40a	0.94a	0.31a	0.45a	75a

Density	ear	Leaf	Stalk	Plant	Silage[a]
Plants A^{-1}	-----------	Ton DM A^{-1}	------------		Ton A^{-1}
12,000	1.04 c	0.29 c	0.61 c	1.94 c	5.5 c
16,000	1.21 c	0.30 c	0.74 c	2.25 c	6.4 c
20,000	1.52ab	0.37 bc	0.95 b	2.84 b	8.1 b
24,000	1.42 b	0.46ab	1.02 b	2.90 b	8.3 b
28,000	1.56ab	0.49a	1.03 b	3.08ab	8.8ab
32,000	1.70a	0.53a	1.24a	3.47a	9.9a

a = Estimate is at 35% dry matter. Values in columns not followed by the same letter are significantly different at the 0.05 level of probability according to LSD test.

matter. The coefficient of determination was R2 0.85 for grain and R2 0.94 for plant dry matter. The conclusion from this was that the highest plant populaton used in this study resulted in the highest yield.

Table 2. Temperature date in 1987 for Gainesville, Florida and day-length for Florida 30^{o}-latitude).

Month	Temperature		Day-length		Rainfall
	Max	Min	7th day	22nd day	
	...........Deg. F.....		.........Hours.........		In.
Jan	66.9	42.6	10.9	11.2	4.2
Feb	70.5	47.0	11.5	11.9	5.4
March	74.0	52.5	12.3	12.7	10.3
April	79.8	50.0	13.3	13.7	0.5
May	86.2	64.3	14.1	14.5	4.3
June	91.4	70.0	14.7	14.7	2.9
July	92.8	72.1	14.7	14.4	3.9
August	93.0	72.7	14.1	13.7	5.4
Sept	89.7	69.4	13.1	12.7	3.7
Oct	79.7	55.5	12.3	11.8	0.3
Nov	75.8	54.3	11.5	11.1	4.3
Dec	72.2	45.7	10.9	10.8	1.2

Table 2 shows the temperatures and day-lengths registered during the year 1987, and in particular during the growing period from August to December. Low day and night temperatures during the ear filling period is one of the major critical limiting factors in the fall in order to obtain high grain yield, in north Florida. This is consistent with Breuer, et al (1976) who reported that during the grain filling period, temperature and photoperiod interact to reduce the number of grain filling days. Most of the dry matter of corn is produced during the 50 to 60 day period from tasseling to maturity (Hanway, 1963; Wright et al., 1983). In our experiment, the last 50 to 60 days of growth was characterized by decreasing day-length and temperature (Table 2).

The date of planting has an effect on the total number of days required to reach 50% tassel. According to Wright et al, (1983), the later we plant in the season in north Florida conditions (February to May), the sooner 50% tasseling and 50% moisture is reached. The flowering date of corn has been advanced by increasing temperature or decreasing photoperiod (Allison and Daynard, 1979; Tollenaar et al., 1979). The photoperiod and temperature affects the number of days to tassel, and this is different for each corn genotype (Hunter et a]., 1977). It is likely that dry matter yield of the whole corn plant, planted in midsummer as a second crop, will be affected, because the time from emergence to tasseling is shortened by short day-lengths and dropping temperatures from August to December. We observed that during the later part of the growth, after silking, certain disuniformity in the number of green and drying leaves occurred, this could be explained by the effect that low day and night temperatures have on the leaves of different ages. According to Alberda (1969), day temperature is the important factor in influencing the chlorophyll concentration in growing leaf parts. Parts subjected to low night temperatures remain fully green and their growth is virtually unaffected. This is an important factor for silage purposes. Nevertheless, FLOPUP shows promising results as a fall crop (Table 1).

Conclusions

All yield variables responded to increased plant population. The maximum grain and who plant dry matter yield of 40 bu A^{-1} and 3.43 ton A^{-1},respectively were obtained at the highest population of 32,000 plants A^{-1}. The ear size and shelling percent were not affected by plant population density. The effect was only in the number of ears. FLOPUP showed promising results as a fall silage crop if well managed. Temperature during the grain filling period is one of the major critical limiting factors in the fall to obtain high grain yield. The short day-length correlated with low temperature, and high insect damage perhaps, will affect the final grain yield. Insect control needs futher research, to determine the most effective and economical control program.

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No-Till Research with Tropical Corn in a Doublecrop System

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Introduction

Mother Nature is a no-till farmer never leaving the earth bare of vegetation. No-till farming is not new, but an old approach adapted to modern machinery and farming. Excessive tillage and poor tillage practices are the primary causes of soil erosion from farmland. Eliminate tillage operations and you also save time and money. Every trip across a field with a tillage tool represents an investment in time and dollars. A need also exists for alternative crops to soybean for use in no-till wheat *[Triticum aestivum* (L.)]doublecropping in the southern USA. While soybean *[Glycine max* (L.) Merr.] predominates, other crops such as grain sorghum *[Sorghum bicolor* (L.) Moench.], sunflower *[Helianthus annuus* (L.)], and temperate corn *(Zea mays* (L.)] have shown varying potentials in doublecropping (Sanford et al.. 1986).

Winter wheat is normally harvested between 1 and 15 June in the S.E. USA. Doublecropped soybean is usually planted about 12 June for optimum yields. Temperate corn following winter wheat is not a suitable double-crop in the S.E. Coastal plain because of the occurrence of damaging insects and disease (Sanford et al., 1988). specifically fall armyworm *(Spodoptera frugiperda* (J.E. Smith)] and southern corn rust *[Puccinia polysora* (Undrew)].

Tropical corn hybrids with satisfactory grain yields at moderate fertility (120 lb N/A) have become available (Taylor and Bailey, 1979). Yet. tropical corn hybrids generally yield less grain than temperate adapted hybrids (Muleba, etal.. 1983) under spring climate (March15 to Aug 26). high fertility, irrigation and low insect and disease intensities. but they may be useful as a nonirrigated late summer crop (June to October) in the S.E. United States.

The study was conducted to 1. determine yield potential of no-till tropical corn with moderate energy input doublecropped after no-till wheat, 2. compare the economics of moderate energy input summer no-till tropical corn with no-till soybean and temperate corn. 3. document the rainfall and air temperature patterns of the June to October growing seasons of moderate energy input tropical hybrids over years.

Materials and Methods

Following the harvest of Florida 302 wheat, tropical corn was planted no-till into winter wheat stubble with a Brown-Hardin Ro-ti1 planter[2] in 30-inch rows at a population density of 18,000 plants/A.

Tropical corn was grown in a moderate energy input system of 120 lb N/A and no irrigation (dryland). Tropical corn (Pioneer X-304C) planting dates were 13 June 1985, 16 June 1986.24 June 1987 , and 8 June 1988. In 1987, Asgrow 5509, a temperate hybrid, was no-till planted as a singlecrop on 26 March in a high energy input system of high fertility (250 lb N/A). irrigation, and population density of 30,000 plants/A. In 1988, Asgrow 5509 was no-till planted at a population density of 18,000 plants/A on 15 June in a moderate energy input system.

The research was conducted at the North Florida Research and Education Center at Quincy, FL on a Norfolk sandy loam soil (fine-loamy, siliceous, thermic. Typic Paleudult) under natural rainfall conditions, for late summer tropical corn, and irrigation, for high energy input spring temperate corn. Herbicides used in the experimental plots were a pre-emerge tank mix of Aatrex (2-chloro -4-ethylamino-6-isopropylamino-s-tri-azine) @1 1/2 qt/A, Lasso (2-Chloro-2'-6'-diethyl-N-(methoxymethyl)-acetanilide] @ 2 qt/A, Paraquat (I, 1'-Dimethyl-4,4-bipyridinium ion as dimethyl sulfate salt) @ 1 pt/A, and a non-ionic surfactant (X-77) at I pt/l00 gal for weed control [primarily morning glory (Ipomoea spp.)]. Each year, ammonium polyphosphate (10-34-0) was banded (@ 20 lb N/A as a starter fertilizer on one side of the row, and Furadan [2-(methoxy carbarnolamino)-benzimidazole] was banded @ 8 lbA behind the planter wheel for lesser cornstalk borer *[Elasmopalpus lignosellus* (Zeller)] control.

In 1985, fall armyworm were sprayed with Lannate **[S-**Methyl-N-((methylcarbamoy1)oxy)-thioacetimidate] July and 16 July @ I 1/2 pt/A. In 1986, Lorsban 4E [O,O-Diethyl 0-(3,5,6-trichloro-2-pyridinyl)-phosphorothioate] @ 3 pt/A was applied for fall armyworm control on I July. Nitrogen was sidedressed at 100 lb NIA on I July 1985 (when tropical corn was 24 to 30 inches high), 100 lb N/A on 8 July 1986(12 inches high) 1,05 lb N/A on 22 July 1987 (12 inches high), and 100 lb N/A on 12 July 1988 (12 inches high). A post-directed spray of 2.4-D (2,4-Dichlorophenoxyacetic acid) @ 1/2 pt/A + Paraquat @ 1 pt/A with a surfactant (X-77) was applied near mid-July of each of the four years for weed control. The temperate hybrid had the same rate of 100 lb N/A sidedressed on 20 April, and 2,4-D + Paraquat as a directed spray 1 week later.

Tropical corn was harvested on 3 October 1985, 2I October 1986, 27 October 1987, and 24 October 1988. The temperate, high-fertility, irrigated, spring-planted plots (Asgrow 5509) were harvested on 27 August in 1987 and the moderate-fertility, no irrigation, spring-planted plots were harvested 24 August 1987; while the summer planted, moderate-fertility, no irrigation plots (Asgrow 5509) were harvested 24 October 1987 from 2 rows, 20 feet long. Grain moisture was determined with an electronic meter and grain yields were corrected to 15.5% moisture.

The temperate, high energy input corn (Asgrow 5509) was grown in adjacent plots at Quincy in the State Performance Trials. The hybrid was planted in a conventional seedbed

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with a Brown-Hardin Ro-til planter on 26 March 1987 after a preplant incorporation of Sutan (S-Ethyl diisobuty-Ithiocarbomate) @ 4.75 pt/A and Aatrex @ 2 qt/A. The corn was fertilized with 250-1O0-200) lb N-P-KIA and irrigated with I inch of water eight times during the growing season.

Experimental design was a randomized complete block each year. There were 3 replications in 1985. 4 replications in 1986, 6 replications in 1987, and 5 replications in 1988. The Stare Yield Performance Trial was also a randomized complete block with 4 replications, and its inclusion was for the purpose of economic analysis of an intensive management system compared to a dryland single- and doublecrop system.

Results and Discussion

Comparisons of grain yields of Pioneer X-304C for all four years are shown in Table 1 and days of planting. tasseling and harvest can be related to air temperature and rainfall data in Figures I. Note that the rainfall period correlates with planting and tasseling followed by a dry period at harvest. Rainfall during the summer growing season (planting date to harvest date) of 1985, 1986. 1987, and 1988 years was 16 inches durinp I 13days, 25 inches during I27 days, I5 inches during 125 days, and 23 inches during 159 days, respectively. The warm temperatures of June and July caused the tropical corn to grow much faster than expected so that the sidedress application of 100 lb N/A at 24-30 inches high in I985 (as recommended with spring-grown temperate corn) was late, reducing the yield, and hence the change in N sidedress signal to 12 inch high tropical corn for 1986, 1987. and 1988. The 1985 tropical corn yields were further reduced by the lodging problem caused by two hurricanes. In 1985. ninety-five percent of the corn lodged 20 to 30^{o} from the vertical but did not fall down. The leaning caused the roots to be exposed during the grain fill period and presumably resulted in less water and nutrient uptake during ear fill. The reduced yield (88 bu/A) of Pioneer X-340C in 1988 (Table I) is probably related to the dry period around tasseling (Fig. I).

The grain yields of Pioneer X-34OC grown in the summer under moderate energy inputs were compared with temperate corn (Asgrow 5509). Moderate fertility and a dry period during April and May of 1987 with no irrigation reduced temperate corn yields from 174 bu/A to 46 bu/A. The summer-grown 1988 temperate corn resulted in 29 bu/A grain yield that had a high incidence of corn earworm [Heliothis *zea (Boddie)]* and rice weevil *[Sitophilus oryzae* (Linnaeus)]l damage. The summer-grown, moderate energy input tropical corn averaged 87 bu/A over the four years and had very little corn earworm or rice weevil damage.

Yield, cost, price and net return for no-till winter wheat, doublecropped soybean, singlecropped and doublecropped dryland tropical corn, and singlecropped temperate corn

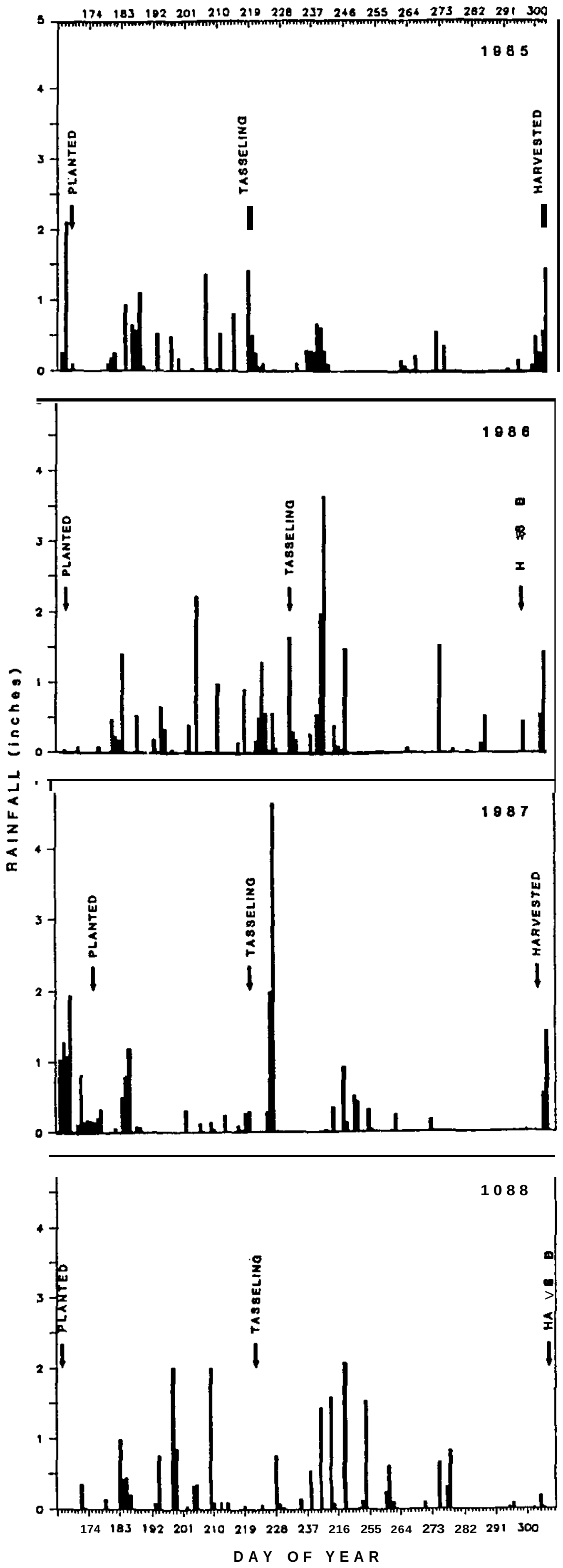

Figure Legends

Figure 1. Rainfall during tropical corn growing seasons of 1985, 1986, 1987, and 1988. Arrows indicate planting, tasseling and harvest date. Days of year are reported in days Julian.

Table 1. No-till tropical corn yields with moderate energy inputs at Quincy, FL for Pioneer X-304C in 1985, 1986, 1987, and 1988.

Year	Yield (bu/A)	t test**	CV
1985	64	c	8.7
1986	98	a	10.3
1987	95	ab	11.5
1988	88	b	10.6

*Columns with the same letter are not significantly different at the 1% level of probility using the Waller-Duncan K ratio t test.

Table 2. Yields, costs/A, costs/bu, projected 1989 prices, and net returns for no-till crops at Quincy, FL.

	No-Till Crop					
	Wheat	Soybean	Tropical Corn		Temperate Corn +/	
		Double	Double	Single-	Irrig.	Dryland
Variable cost/acre	82	90	120	140	240	I25
Fixed cost/acre	30	30	30	40	110	30
Total cost/acre	112	120	150	180	350	155
Yield (bu/acre)	47	25	87	87	174	49
Total cost/bu	2.38	4.80	1.72	2.07	2.01	3.16
Price ($/bu)	4.10	7.40	2.60	2.60	2.60	2.60
Net return/bu	1.82	2.60	0.88	0.53	0.59	-0.56
Net return/acre	X0.84	65.00	76.56	46.11	102.66	-27.44

+/Temperate corn singlecropped only

(irrigated and dryland) are displayed in Table 2. Yields are from the experiments, cost estimates are based upon the cultural practices used in the experiments and prices are projections of 1989 market prices. Dryland temperate corn is the only singlecrop with a projected negative net return. All other crops have a projected positive net return. The anticipated net return from an acre of high energy input (irrigated) temperate corn (spring planted) are about $35 greater than that of an acre of singlecropped, moderate energy input tropical corn (summer planted).

No-till doublecropping reduces production costs of both soybean and tropical corn. The cost savings in tropical corn is $0.35/bu or about $30/A. Doublecropped tropical corn returns almost $18/A more than double-cropped soybean.

The advantage of no-till tropical corn grown during the summer lies in the fact that good yields can be obtained with moderate economic inputs by taking advantage of the summer rains that are fairly dependable for much of the S.E. Coastal Plain during the period from late June through early September, which corresponds to the period of highest tropical corn need, and a predictable early fall drought for maturity and harvest. The dry fall permits few weeds to germinate and grow as they do when temperate hybrids mature in late July and early August. Early in the growing season, IPM practices must be adhered to for control of lesser cornstalk borer and fall armyworm, but we have observed that tropical corn husks are tighter than temperate hybrids making it less susceptible to corn earworm (aparticularly bad fall pest), immune to corn smut *[Ustilago maydis* (CD) Cda.), and with little incidence of aflotoxin *(Aspergillus* spp.). The exterior of the kernel is so hard the rice weevils find it difficult to enter the kernel and therefore damage to tropical corn was less than temperate corn when allowed to stand in the field after maturity. Fertility inputs for corn production are also lower in a doublecropping program because the tropical corn can utilize residual fertility from the previous crop. In general, no-tillage farming practices have proven successful for growing tropical corn in north Florida

Acknowledgements

Our thanks to B.T. Kidd, Biological Scientist II and E. Brown, Agricultural Technician IV; North Florida Research and Education Center, University of Florida, Quincy, FL; for plot preparation and management, data collection, computer processing. and data illustration.

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Conservation Tillage in Soybean and Corn in the South Carolina Coastal Plain

R.E. Sojka* and W.J. Busscher[1]

Abstract

Numerous variations of conservation tillage (CT) systems have been adopted for soybean, corn and double-crop wheat grown on Coastal Plain Ultisols. A systematic investigation of the effect of these variations in cultural practices on yields was needed. A long term tillage study was established in Florence, SC to study these variations in conservation tillage systems. Soybean yields were favored by CT but were reduced by drilling. Burning of double-crop residues showed no yield advantage. Corn yields were slightly reduced by conservation tillage systems in which residues were left standing at planting. Double-crop yields were greatly increased by deep primary tillage. Double-cropped wheal and reduced operations with CT in soybean increased cash returns. However, caution is still in order when considering CT for corn in the Coastal Plain.

Introduction

Conservation tillage (CT) is a broad term as applied to farming practices in the SC Coastal Plain. A range of farming practices and rotations are often combined to create production systems suitable to a farmer's particular needs or perception of needs. These combinations of practices are the result of various factors including changing market prices and their influence on rotational schemes, equipment flexibility, pest control considerations, and the need to manage excessive accumulation of surface residues. Because of dense root-restrictive subsoil horizons in most Coastal Plain Ultisols, nearly all CT systems imply in-row subsoiling in conjunction with planting (Sojka et al.. 1984; Busscher ct al., 1986).

In addition to rotation of corn *(Zea mays* L.) and soybean *(Glycine max* (L.) Merr.) common system components in South Carolina often include Fall cover crops or double-cropping with small grains, Fall disking. Fall fallow (no disking until Spring, but without a cover crop). Spring disking or spraying of cover crops two to three weeks prior to planting, Spring disking or spraying of cover crops immediately before planting and Fall or Spring burning of double-crop small grain stubble and residues. Small grains used in double-cropping and for cover cropping can include rye *(Secale cereale* L.), wheat *(Triticum aestivum* L.), and barley *Hordeum vulgare* L.). Drilling of soybean after double-crop small grains has gained acceptance in some areas, especially if soybean planting is delayed beyond early June. However, this eliminates in-row subsoiling.

In order to compare these kinds of variations, two large field experiments were conducted in adjacent fields. The studies were conducted simultaneously to allow observation of annual meteorological effects on related treatments of a corn and soybean rotation.

Methods and Materials

These studies were conducted from I982 to 1985 at the Coastal Plains Soil and Water Conservation Research Center near Florence, SC. Two fields were established. Field #I was the continuation of a long term tillage study (Campbell, et al.. 1984a,b) with corn and soybean rotation in the plots going back to 1980. Field #2 was established in the Fall of 1981 with the planting of the study area to barley. The barley crop was completely lost to a severe frost in Spring of 1982 at the time of flowering, and was managed subsequently as a cover crop. Prior to establishment of these studies the fields had been alternately "weed fallowed" and cropped to Tobacco (Nicotiana tabacum L.) for several decades. The soil in the study area was classified as Norfolk sandy loam (fine-loamy, siliceous, thermic Typic Paleudult).

The study was in a randomized split block design in four replications, with Tillage main plots sometimes split for cultivar or planter subplots as indicated in tables I and 2. Fertilizer was surface granular applied prior to each crop's operations according to South Carolina standard production recommendations. Liming was surface applied at a rate of 1000 lb/acre $CaC0_3$ equivalent applied each Spring prior to row-crop planting. Herbicides and pesticides follow SC Exp. Stn recommendations and were as reported for the early years of the study of the study (Campbell, et al., 1984a, b).

Planting for all tillage regimes was with a Brown-Harden Super Seeder', except for drilling operations, which were with a KMC Unidrill. Drilled soybean plots were subsoiled on 30 in. spacing in a separate operation immediately prior to planting. Plots were 135 ft by 45 ft. Row Crops were on 30 in. spacing. The Unidrill was 10 ft wide, with 7 in. drill spacing. When row planting vs drill comparisons were made th ree drill passes were planted alongside one six-row super-seeder pass to fill the plot area. Corn and Soybean were planted 19,000 and 80,000 plants per acre respectively; and wheat was planted at a rate of 60 lbs of seed per acre. A 125 ft pass through the center of each subplot with a 60 in. wide plot-combine constituted the harvest area for each subplot. In the fall of 1984 the corn in the field designated as field #2 was followed by wheat in treatments 3. 4, 5, and 6. using no-till planting with the KMC Unidrill, or field preparation by disking, moldboard plowing, or chisel plowing. respectively to establish the treatments.

A schematic summary of cultural operations for the duration of the study is presented in table I and 2. Treatment I is a conventional tillage treatment, treatment 2 is a reduced tillage treatment, and treatments 3 through 6 are conservation tillage treatments. Analysis of variance and paired treatment comparisons of yields were accomplished using appropriate

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Table 1. Schematic of field surface-residue/tillageoperations for FIELD #1 for 1983, 84, and 85.

Trtmt	barley soybean 1983	wheat	soybean 1984	corn 1985
1	disk/H	disk/H	disk/H	disk/H
	disk/M	disk/M	disk/M	disk/M
	PPI		PPI	plant
	plant		plant	spray/PE
2	disk/H	disk/H	disk/H	disk/H
	disk/L		disk/L	disk/L
	plant		plant	plant
	spray		spray/PE	spray/PE
3	stubble	stubble	stubble	stubble
	plant	plant	plant	spray/L
	spray/PE	spray/E	spray/PE	plant
		harvest/E		spray/PE
4	stubble	disk/H	stubble	stubble
	burn/L	plant	burn/L	spray/E
	plant	spray/E	plant	plant
	spray/PE	harvest/E	spray/PE	spray/PE
5	stubble	stubble	stubble	stubble
	burn/L	plant	burn/L	disk/E
	disk/L		disk/L	plant
	plant		plant	spray/PE
	spray/PE		spray/PE	
6	stubble	disk/H	stubble	stubble
	disk/L	plant	disk/L	disk/L
	plant		plant	plant
	spray/PE		spray/PE	spray/PE

The Letters H, M, E, and L following operations refer to immediately post-harvest, multiple, early, or late operations in the periods between crops. PPI indicates preplant incorporation of soil-applied herbicides. PE indicates pre-emergence spray of soil surface-applied herbicides. The term "spray" indicates application of either paraquat or glyphosate and "spray/PE" indicates tank mixing of both herbicide systems.

models within SAS for each segment of the study (SAS Institute, Cary, North Carolina).

Results and Discussion

The yields from fields #1, and #2 over the course of the study are presented in tables 3 and 4. Treatments 3, 5,and 6 in field #1 and treatments 2, 4, 5, and 6 in field #2 were statistically indistinguishable from the highest yield for all crops and all years of the study (excluding wheat response to primary tillage in treatment 4 in 1985). Treatments 3, 4, 5, and 6 were all variations of conservation tillage. Treatment 2 utilized no double cropping or planted cover crop but limited tillage to a single disking immediately after harvest and a single disking immediately prior to planting.

Treatment 1, which was the most intensive form of conventional tillage produced the significantly lowest soybean yields in field 1 in 1983 and 1984, and in field 2 in 1985. Though not significantly different treatment 1 also produced among the numerically lowest soybean yields in field 2 in 1982 and 1983 as well. Although the highest yielding soybean treatment varied with field and year, there was a trend for increased yield with one form or another of conservation tillage. These results agreed with earlier findings (Campbell et al., 1984b). Drilling reduced soybean yields in field #2 in 1983 in all but treatment 5, which is consistent with observations of yield reduction in drilled soybean where available soil water was limited (Sojka, et al., 1988). Paired treatment analysis showed no significant effect of burning residues but a significant yield advantage of reduced tillage over conventional.

Table 2. Schematic of field surface-residue/tillage operations or FIELD 2 for 1982,83,84 and 85.

Trtmt	barley soybean 1982	wheat	soybean 1983	corn 1984	wheat	soybean 1985
I	disk/H	disk/H	disk/H	disk/H	disk/H	disk/H
	disk/M	disk/M	disk/M	disk/M	disk/M	disk/M
	PPI		PPI	plant		PPI
	plant		plant	spray/PE		plant
2	disk/H	disk/H	disk/H	disk/H	disk/H	disk/H
	disk/L		disk/L	disk/L		disk/L
	plant		plant	plant		plant
	spray/PE		spray/PE	spray/PE		spray/PE
3	stubble	stubble	stubble	stubble	stubble	stubble
	spray/L	plant	plant	spray/L	plant	plant
	plant	spray/E	spray/PE	plant		spray/PE
	apray/PE	harvest/E		spray/PE		
4	stubble	disk/H	stubble	stubble	disk/H	stubble
	spray/E	plant	burn/L	spray/E	disk/M	burn/L
	plant	spray/E	plant	plant	plant	plant
	spray/PE	harvest/E	spray/PE	spray/PE		spray/PE
5	stubble	stubble	stubble	stubble	plow/L	stubble
	disk/E	plant	burn/L	disk/E	plant	burn/L
	plant		disk/L	plant		disk/L
	spray/PE		plant	spray/PE		plant
			spray/PE		spray/PE	
6	stubble	disk/H	stubble	stubble	Chisel/L	stubble
	disk/L	plant	disk/L	disk/L	plant	disk/L
	plant		plant	plant		plant
	spray/PE		spray/PE	spray/PE		spray/PE

The Letters H, M, E, and L following operations refer to immediately post-harvest, multiple, early, or late operations in the periods between crops. PPI indicates preplant incorporation of soil-applied herbicides. PE indicates pre-ermegence spray of soil surface-applied herbicides. The term "spray" indicates application of either paraquat or glyphosate and "spray/PE" indicates tank mixing of both herbicide systems.

Corn yields were significantly lowest in treatment 4 in field # I in 19885 and numerically lowest in treatment in field #2 in 1984. In field #2 in 1983 treatment 3 produced only 1 bushel more corn than treatment 4. Treatments 3 and 4 represent no-till planting of corn into standing residues. The highest corn yields produced in field #1 were from treatments 1 and 6. Although none of these high yield trends were significantly greater than the other treatments, they all originated from treaments in which corn was planted in disked ground. Paired treatment comparisons showed a significant

Table 3. Yields for soybean, wheat, and corn for treatment in field 1.

Year	Crop	Variety	Treatment 1	2	3	4	5	6
			bu/a					
1983	Soybean	Braxton	24.7	27.6	32.6	36.6	25.8	28.2
		C 488	27.4	29.8	36.5	35.4	33.0	30.8
		C 237	30.2	31.6	38.0	36.2	33.6	33.6
		Mean	27.4b	29.7b	35.7a	36.1a	30.8ab	30.9ab
1984	Wheat	C 797	--	--	49.9a	49.2	50.7a	50.7a
1984	Soybean	C488	19.8b	22.8ab	22.7ab	26.3a	22.3ab	20.2ab
1985	Corn	P 3572	101ab	106a	103ab	97b	106a	100ab

Numbers in the same row followed by the same letter indicate no difference as determined by LSD comparison at the 5% level of probability.

Table 4. Yields for soybean, wheat, and corn for treatment in field 2.

Year	Crop	Variety	Treatment 1	2	3	4	5	6
			bu/a					
I982	Soybean	C237	34.5a	39.0a	34.2a	33.7a	35.2a	35.7a
1983	Wheat	C 797	--	--	24.7a	21.2a	21.@a	20.7a
1983	Soybean	C 488	36.1	37.1	35.4	37.7	35.8	41.1
		C 488*	33.8	32.7	30.8	36.2	38.0	35.8
		Mean	35.3ab	34.9ab	33.1b	37.0ab	36.9ab	38.4a
1984	Corn	P 3572	139a	131a	129a	128a	135a	138a
I985	Wheat	C 916	--	--	19.2	26.4	45.7	28.8
		C983	--	--	29.1	36.9	47.1	41.7
		HX 3021	--	--	**39.**1	46.3	58.7	48.8
		HX 3022	--	--	34.7	42.4	50.0	42.2
		Mean	--	--	30.5c	38.0b	50.4a	40.4b
1985	Soybean	C368	35.3c	46.3a	40.2bc	42.8ab	41.9ab	43.9ab

*Drilled.

Numbers in the same row followed by the same letter indicate no difference as determined by LSD comparison at the 5% level of probability.

positive yield effect of conventional tillage and disking over planting directly into residue for corn. These results coincide with earlier observations from related work (Campbell et al.. 1984a; Karlen and Sojka, 1985).

Wheat did not produce clear responses to the four reduced tillage regimes compared in field #1 in 1984 and field #2 in 1983. This prompted a comparison of primary tillage operations to prepare for this double-crop between row-crop sequences. The results from field #2 in 1985 clearly indicated a positive response to deep primary tillage for double-crop wheat, with yield increasing significantly with tillage intensity, in the order plow x chisel x disk x no-till.

Conclusion

Various CT systems have been adapted for soybean, corn and double-crop wheat grown on Coastal Plain Ultisols. Burning of double-crop residues showed no yield advantage. Soybean yields were favored by CT but were reduced by drilling. Corn yields were slightly reduced by conservation tillage systems in which residues were left standing al planting. Double-crop yields were increased by deep primary tillage. Double-cropped wheat and reduced operations with CT in soybean have the potential to increased cash returns. Caution is still in order when considering CT for corn in the Coastal Plain.

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Potential of Bladex and Classic in Stale Seedbed Soybeans

M. E. Kurtz and W. L. Barrentine[1]

Introduction

Several reasons have been proposed for producing a crop using reduced tillage; the most important is the potential lessening of soil erosion. Other reasons included lowered production costs (6)and increased crop yields (2). There have been reports of poor weed control in reduced and no-tillage systems (3,4,) while other researchers have reported that plant residues left on the soil surface control weeds (1,7).

Although cyanazine (Bladex) is not currently labeled for use in soybeans, research has shown its effectiveness in controlling weeds in soybeans with little injury to the crop (5) depending upon herbicide placement.

The purpose of this experiment was to determine the effectiveness of Bladex and chlorimuron (Classic) alone or in combination as preplant foliar herbicides in a reduced tillage system.

Materials and Methods

A field experiment was conducted on Sharkey clay (very fine, montmorillonitic, thermic Vertic Haplaquept) in 1988, at Stoneville, MS. Treatments included Bladex at 0, 0.25, 0.375, and 0.5 lb ai/A and Classic at 0, 0.0078, and 0.0625 lb ai/A alone and in combination for preplant burndown control of pitted morningglory *(Ipomoea lacunosa* L.) in the 0-4 leaf stage, prickly sida *(Sida spinosa* L.) in the 0-6 leaf stage, common cocklebur *(Xanthium stramarium* L.) in the 2-6 leaf stage, johnsongrass [*Sorghum halepense* (L.)Pers.] in the 3-6 leaf stage, redvine [*Brunnichia ovata* (Walt.) Shinners] 24 inches in diameter, curly dock *(Rumex crispus* L.) 8 inches in diameter, and Pennsylvania smartweed *(Polygonum pensylvanicum* L.) 8 inches in diameter. The 0.0078 lb/A rate of chlorimuron is a labeled rate when applied postemergence as Classic in soybeans. When applied preplant incorporated or preemergence, the 0.0625 lb/A rate of chlorimuron is a labeled rate when applied as a component of Canopy

The field was previously cropped in soybeans and was chisel plowed and disked twice in February of 1988. All herbicide treatments were mixed with Agridex I.25% (v/v), a petroleum based crop-oil concentrate, and applied on May 5, 1988, with a tractor-mounted compressed air sprayer calibrated to deliver 20 gallons of spray solution per acre. Soybeans 'Epps' were planted on May 25, 1988. Experimental design was a randomized complete block with 3 replications. Plots were 4, 40-inch rows, 50 feet long. A visual rating of weed control was recorded for each weed species 2 weeks after treatment. Soybean yield was obtained by mechanically harvesting the center two rows of each plot. Data were subjected an to analysis of variance using a 4 x 3 factorial arrangement of treatments and means were compared using a Least Significant Difference Test at the P=0.05 level of significance.

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Results

Pitted Morningglory

Bladex alone provided only 73 to 82% control (Table 1), while both rates of Classic significantly increased control over all rates of Bladex. These data suggest that Classic could be used alone to achieve excellent preplant burndown of pitted morningglory, and would be more effective than Bladex alone.

Table 1. Preplant burndown control of pitted morningglory by Bladex and Classic.

Bladex	Classic (lb ai/acre)		
(lb ai/acre)	0	0.0078	0.0625
	------------------------%	------------------------	
0	0	91	97
0.25	73	92	93
0.375	14	94	97
0.5	82	89	97

LSD (0.05) = 10 for comparison of any two means

Prickly Sida

Neither Bladex nor Classic were effective in controlling prickly sida (Table 2). Even though some of the tank-mixtures provided significant increases in control, no combination provided greater than 80% control.

Table 2. Preplant burndown control of prickly sida by Bladex and Classic.

Bladex	Classic (lb ai/acre)		
(lb ai/acre)	0	0.0078	0.0625
	------------------------%	------------------------	
0	0	3	7
0.25	32	53	28
0.375	43	33	37
0.5	22	20	38

LSD (0.05) = 35 for comparison of any two means

Common Cocklebur

Bladex alone was not effective in controlling common cocklebur (Table 3), but control was significantly increased

Table 3. Preplant burndown control of common cocklebur by Bladex and Classic.

Bladex	Classic (lb ai/acre)		
(lb ai/acre)	0	0.0078	0.0625
		%	
0	0	99	99
0.25	27	99	99
0.375	30	99	99
0.5	43	99	99

LSD (0.05) = 5 for comparison of any two means

with the addition of Classic. Classic alone provided excellent control and was effective at the lowest rate. Bladex was not needed for control.

Johnsongrass

Johnsongrass was not controlled with Bladex or Classic applied alone at any rate (Table 4). Only Bladex (0.5 lb/A) + Classic (0.0078 lb/A) provided increased control over Bladex alone, however the control (35%) was unacceptable.

Table 4. Preplant burndown control of johnsongrass by Bladex and Classic.

Bladex	Classic (lb ai/acre)		
(lb ai/acre)	0	0.0078	0.0625
		%	
0	0	23	47
0.25	7	17	12
0.375	10	23	25
0.5	10	35	27

LSD (0.05) = 19 for comparison of any two means

Redvine

Although there was no rate response associated with either Bladex or Classic (Table 5), there were some significant responses to tank-mixing. As seen with prickly sida and johnsongrass, effective control was not achieved even by tank-mixing.

Curly Dock

Bladex alone was not effective in controlling curly dock (Table 6). However, Classic used alone at the high rate resulted in significantly better control than did any rate of Bladex. Tank mixing with Bladex did not increase control above the high rate of Classic.

Table 5. Preplant burndown control of redvine by Bladex and Classic.

Bladex	Classic (lb ai/acre)		
(lb ai/acre)	0	0.0078	0.0625
		%	
0	0	18	8
0.25	22	29	32
0.375	28	40	18
0.5	22	48	20

LSD (0.05) = 10 for comparison of any two means.

Table 6. Preplant burndown control of curly dock by Bladex and Classic.

Bladex	Classic (lb ai/acre)		
(lb ai/acre)	0	0.0078	0.0625
		%	
0	0	37	85
0.25	22	38	78
0.375	28	43	83
0.5	30	52	90

LSD (0.05) = 7 for comparison of any two means

Pennsylvania Smartweed

Pennsylvania smartweed control increased with increased rates of Classic (Table 7). Tank-mixtures did not increase control over Classic alone at either rate. However, the tank-mixtures of Bladex and the high rate of Classic significantly increased control over each rate of Bladex.

Table 7. Preplant burndown control of Pennsylvania smartweed by Bladex and Classic.

Bladex	Classic (lb ai/acre)		
(lb ai/acre)	0	0.0078	0.0625
		%	
0	0	53	82
0.25	35	53	73
0.375	68	57	83
0.5	28	53	81

LSD (0.05) = 16 for comparison of any two means

Soybean Yield

Bladex applications did not result in increased yields over the untreated control (Table 8). but yield was significantly increased as rate of Classic increased. The tank-mixtures of

Table 8. Soybean yield as affected by preplant burndown applications of Bladex and Classic.

Bladex	Classic (lb ai/acre)		
(lb ai/acre)	0	0.0078	0.0625
	bu/acre		
0	15	20	26
0.25	18	18	24
0.375	16	20	28
0.5	16	18	29

LSD (0.05) = 5 for comparison of any two means.

Bladex and the high rate of Classic increased yields significantly over each rate of Bladex alone, but not over Classic alone at the high rate.

Summary

The effectiveness of preplant burndown applications of Bladex and Classic for control of pitted morningglory, prickly sida, common cocklebur, johnsongrass, redvine, curly dock, and Pennsylvania smartweed, was found to be dependent upon weed species.

Neither herbicide alone or in combination provided acceptable control of prickly sida, johnsongrass, or redvine. Bladex at 0.5 lb/A resulted in 82% control of pitted morningglory while Classic alone or any tank-mixture provided >89%. Classic at any rate or tank-mixture resulted in 99% control of common cocklebur, while effective control of curly dock or Pennsylvania smartweed was only achieved with the high rate of Classic or the high rate of Classic tank-mixed with the two highest rates of Bladex.

Soybean yields were significantly increased over the untreated control and all Bladex treatments, when the high rate of Classic was used. The results of this experiment show that where acceptable control of treated weeds was achieved, Classic had the most significant effect in offering that control.

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No-tillage Yield of Double-cropped Rye and Soybean in Relation to Nitrogen and Potassium Fertilization

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Abstract

Fertility requirements for no-tillage (NT) double-cropping (DC) systems need to he studied. The purpose of this research was to determine the N and K feriilizer requirements in a 11-yr-old NT rye (*Secale cereale* L.) -soybean (*Glycine max* L.) DC system. 'Wrens Abruzzi' rye was seeded in November 1985 and 1986 followed each year by 'Centennial' soyhean planted in mid-June in 10 in-wide rows using a NT 'Tye" drill. A randomized complete block design with four replications was used. Main plots consisted of five N rates in a randomized complete block with four replications. Each main plots had five sub plots of K. Fertilizer had a positive effect on rye whole plant and grain yield, other rye variables and soybean seen yield. Soybean seed yield responded positively to residual K which had been applied to the rye crop.

Introduction

Small grain followed by soybean (*Glycine max* L.) is the agronomic double-cropping (DC) system most widely grown in the United States and probably in the world. Tillage and related management practices for this DC system have been evaluated by numerous researchers (Gallaher, 1977a; Gallaher, 1977b; Gallaher and Weaver. 1982; Hargrove et al., 1982; Sanford, 1982;). A larger variety of small grain-soybean DC systems (Soybean followed by rye (*Secale cerealw* L.) grain (Westberry and Gallaher. 1979), wheat (*Triticum aestivum* L.) after soybean or dormant summer perennial grasses (Wright, 1984), soybean or grain sorghum (*Sorghum bicolor* L.) followed by oat (*Avena sativa* L.) (Ortiz and Gallaher, 1984), and others suggested by Gallaher et ai. (1980)) can be practiced in the prevailing warm climate of Florida. Hargrove et al. (1983) indicated that wheat growth, N status, and grain yield are influenced by the previous crop and are important to the management of DC systems. Gallaher (1977a) mentioned that "In general that DC systems were fertilized with leas N and about equal or slightly more P and K than the sum of what would be recommended for the winter and summer crops if. grown separately as monocrops." Post (1983) indicated that soybean appeared to leave sufficient N to meet the needs of rye in a no-tillage (NT) rye-soybean DC system. However, insufficient soil K may be a problem when such DC is practiced. This study was

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conducted to evaluate the yield response of a 11-yr-old NT rye-soybean DC system to N and K fertilizer.

Materials and Methods

"Wrens Abruzzi" rye was seeded at the rate of 90lb. A^{-1}on 20 November 1985, and 1986. Following the rye crop, "Centennial" soybean was planted in mid-June 1986 and 1987 in 10 in-wide rows using a NT "Tye" drill. Soybean was seeded at the rate of 9 seed ft^{-1} of row. Standard cultural and pest management practices were carried out as required for each crop (Table I).

Double-cropping of rye and soybean during November 1985 to October 1986 constituted the first cropping cycle (CC) (85-86) and from November 1986 to October 1987 constituted the second CC (86-87). Plots used during the 86-87 CC were adjacent to plots used during the 85-86 CC. Identical data were collected for both the 85-86 and 86-87 CC.

A randomized complete **block** design with four replications nested within CC in a modified 5 x 5 factorial with N assigned at random and K assigned at random within each N treatment was used. Main plots consisted of five N rates (0, 35, 70, 105, and 140 lb a^{-1}) each containing five sub-sub-plots of K (0,40,80, 120, and 160lb A^{-1}). Sub-sub-plots were 10 by 16 ft in size.

Ammonium nitrate and muriate of potash were used as sources of N and K, respectively. All K applications were made at rye planting time while N was applied l/3rd at planting and 2/3rd at the beginning of February. Fertilizer was applied only to the rye crop in a cycle.

A 20 in. by 10ft (17 ft^2) quadrant from the center of each plot was used to collect samples for evaluating rye whole plant dry matter (WPDM), rye grain yield (GYL), percent ground cover of rye (GC), and yield of soybean grain (SY). A 3.3ft. by 10 in (2.75 ft^2) quadrant was also used to evaluate grain yield (GY2), head weight (HW), percent grain $head^{-1}$ (PGH), and head area index (HAI) of the rye. Testing of differences among treatments was made by the Fisher Protected Least Significant Difference Test (FPLSD) (Steel and Torrie, 1980; Chew, 1976).

Results and Discussion

No interactions occurred in this experiment. Highest yields of rye WPDM were obtained when 105 lb NA^{-1} were applied (Table 1) during the 85-86, 86-87, and CC avg. Response to N increased linearly up to the 105 lb A fertilizer rate and then decreased at the highest N rate (I40 lb A^{-1}). Similar results were observed for rye GYI, even though no differences were found for the 86-87 CC year according to the F-test (P is less than 0.05). When compared to the 0 lb K A^{-1} rate, rye WPDM responded to k application at all rates during the 85-86. 86-87, and CC avg (Table I). There was a slight trend toward higher yields of rye WPDM when higher K rates were applied. An analogous trend was observed for the response of rye GYI to K application. In this case statistical differences were found only to the highest rate of K applied (160 lb A^{-1} for the 85-86. 86-87, and the CC avg, respectively (Table 1).

Soybean seed yield did not respond to residual N. However, a trend of greater SY was observed from increasing N rates applied to the rye crop. Soybean seed yield showed a response to the residual K at the 40 lb K A^{-1}rate for the 85-86 and the CC avg, and to the 160lb K A^{-1}rate for the 86-87 CC (table 1). This indicated that the K applied to the rye crop was cycled through the rye residue and returned to the soil to be used by the succeeding soybean crop. These results reinforce Post's (1983) conclusions that "In general, DC of rye followed by soybean efficiently recycles nutrients from crop to soil" (p.viii).

Rye PGC responded significantly to the application of 35 lb N $A^{-1}$for the 85-86 CC and 140 lb N A^{-1} for the CC avg (Table I). Rye PGC responded to the application of 120 lb K A^{-1} during the 85-86 CC. A response to the application of 40 lb K A^{-1} was observed for this variable for both the 86-87 and the CC avg. A linear increase in rye PGC in response to both N and K applications was observed for the 86-87 CC and the avg CC. Greater PGC could be important to protect the soil against water and wind erosion. This could be an important factor when the rye crop is grown for the dual purpose of either dry matter (pasture grazing and/or silage) or grain production and as a winter cover crop for erosion control.

Rye HA1 responded to the application of 105lb N A^{-1}in all years and showed a linear increase in response to N for the 85-86 and avg CC (Table I). Rye HA1 increased linearly up to the rate of 105 lb N $A^{-1}$and decreased at the highest N rate of 140 lb N A^{-1} during the 86-87 CC. A similar response was observed for rye HW. Rye HA1 responded to the application of 80 lb K A^{-1} during the 85-86 CC and 40lb K A^{-1} during the 86-87 and the CC avg, respectively (Table I). Rye HW responded to the application of 80 lb K A^{-1} during the 85-86 and to 80 lb K A^{-1} for the CC avg (Table I).

Rye GY2 showed a response to the application of 105 lb N A^{-1} during both the 85-86 and the CC avg. Rye GY2 increased linearly up to the rate of 105lb N $A^{-1'}$ and decreased at the highest N rate of 140 lb N A^{-1}(FPLSD) 0.05) (Table I). A similar trend was observed during the 86-87 CC. A response of rye GY2 to the application of 80 lb K$A^{-1}$was observed for the 85-86 and the CC avg (FPLSD 0.05) (Table 1)A trend of an analogous behaviour was observed during the 86-87 CC. Variability increased when the smaller area was used (2.75 ft^2) as compared with the larger 17 ft^2 sampling area.

Rye PGH responded to the application of 105 lb N A and 80 lb K A^{-1} during the 85-86 CC (FPLSD 0.05) (Table 1). The total grand mean for the rye PGH was 37% for the CC avg. This could be used to indicate how rye heads reached only about a third of their total potential grain filling capacity. This could be explained by the early increase in temperatures and the later freezes that occurred during the spring that is usual under Florida subtropical climate. Thus, even though the rye heads were fully developed, the rye grain filling process was disrupted by the late low temperatures.

Table 1. Rye and soybean yield variables as affected by N and K fertilization.

Yield variable	N rate	Cropping cycle 85-86	86-87	Avg	K rate	Cropping cycle 85-86	86-87	Avg
	$lb A^{-1}$		$Ton\ A^{-1}$		$lb A^{-1}$		$Ton\ A^{-1}$	
Rye WPDM[a]	0	0.80	0.93	0.87	0	1.51	1.42	1.47
	35	1.38	1.29	1.34	40	1.74	1.60	1.67
	70	1.91	2.00	1.96	80	1.74	1.87	1.81
	105	2.31	2.27	2.29	120	1.87	1.87	1.87
	140	2.27	2.09	2.18	160	1.83	1.87	1.85
FPLSD[b]		0.33	*0.51*	0.27		0.18	0.22	1.13
	$lb A^{-1}$		$Bu\ A^{-1}$		$lb A^{-1}$		$Bu\ A^{-1}$	
Rye grain (GY1)	0	60.4	3.2	4.8	0	11.1	4.8	8.0
	35	7.8	4.8	6.3	40	10.5	4.5	7.5
	70	12.2	5.9	9.1	80	11.8	6.0	8.9
	105	16.1	7.2	11.7	120	11.8	5.2	8.5
	140	14.8	5.6	10.2	160	12.1	6.5	9.3
FPLSD		3.5	NS	2.5		1.8	1.6	1.1
	$lb A^{-1}$		$Bu\ A^{-1}$		$lb A^{-1}$		$Bu\ A^{-1}$	
Soybean seed yield	0	32.6	20.8	26.7	0	26.7	20.8	23.8
	35	32.6	22.3	27.5	40	34.1	23.7	28.9
	70	31.2	22.3	26.8	80	32.6	25.2	28.9
	105	35.6	28.2	31.9	120	34.1	26.7	30.4
	140	32.6	31.2	31.9	160	34.1	28.2	31.2
FPLSD		NS	NS	NS		5.9	4.5	3.7
	$lb A^{-1}$		%		$lb A^{-1}$		%	
Rye ground cover	0	47	43	45	0	45	50	58
	35	67	48	58	40	70	55	63
	70	75	53	64	80	71	56	64
	105	83	61	72	120	74	56	65
	140	82	68	75	160	72	57	65
FPLSD		17	11	9		6	5	4
	$lb A^{-1}$		$in^2\ ft^{-2}$		$lb A^{-1}$		$in^2\ ft^{-2}$	
Rye head area index	0	2.0	2.0	2.0	0	2.9	3.0	3.0
	35	2.7	3.2	2.9	40	3.5	4.0	3.8
	70	3.8	4.5	4.1	80	3.9	4.2	4.0
	105	3.8	5.2	4.5	120	3.8	4.0	3.9
	140	4.6	4.5	4.5	160	3.9	4.2	4.0
FPLSD		1.2	1.2	0.7		0.9	0.6	0.4
				$lb A^{-1}$				
Rye head weight[c]	0	530	280	410	0	690	290	490
	35	600	370	490	40	710	370	540
	70	750	440	600	80	800	430	620
	105	1000	490	750	120	780	390	590
	140	870	410	640	160	800	390	600
FPLSD		190	170	120		120	NS	75

	$lb A^{-1}$		$Bu A^{-1}$		$lb A^{-1}$		$Bu A^{-1}$	
Rye grain (GY2)[c]	0	6.4	3.3	4.9	0	8.4	5.1	6.8
	35	7.8	6.5	7.2	40	9.1	6.5	7.8
	70	10.0	7.5	8.8	80	11.9	7.5	9.7
	105	16.1	8.3	12.2	120	10.3	6.4	8.4
	140	12.4	7.2	9.8	160	11.8	6.8	9.3
FPLSD		4.8	NS	3.2		2.7	NS	1.9
	$lb A^{-1}$		%		$lb A^{-1}$		%	
Percent grain $head^{-1}$	0	30	42	36	0	35	43	39
	39	29	44	37	45	29	39	34
	78	32	40	36	90	35	41	38
	117	39	39	39	135	34	38	36
	156	38	27	38	180	34	40	37
FPLSD		8	NS	NS		6	NS	NS

"Whole plant dry matter, [b]Fisher Protected Least Significant Difference Test ($P < 0.05$, NS = not significant ($P = 0.05$), 'Rye head area index, rye head weight, rye grain yield (GY2), and percent grain $head^{-1}$ were obtained from a harvested area of 2.75 ft^2, 17 ft^2 harvested area was used for all other variables.

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Wheat Response to Tillage Systems and Planting Dates

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Introduction

Wheat *(Triticum aestivum* L.) is grown on approximately 400,000 acres in Mississippi. Conventional tillage, chisel + disking or disking are the most common seedbed preparation methods used on these acres. However, tillage increases the erosion potential. No-tillage and paraplow are two possibly viable reduced tillage systems for growing wheat in North Mississippi. The objectives of this study were to evaluate wheat growth and yield response to different production systems (tillage-row spacing combinations) and planting dates.

Materials and Methods

The study was conducted from 1985 through 1988 on the same site of an Atwood silt soil with a 3% slope at the

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The experimental design was a randomized complete block with treatments arranged as a split plot with four replications. Wheat planting dates were whole plots (Table 1) and production systems (tillage-row spacing combinations) were subplots. The tillage treatments were (1) fall chisel + disk, (2) fall paraplow, and (3) no-tillage. The chisel + disk treatments were used with three wheat row spacings: planting in 4- and 8-in rows, and a broadcast 2x seeding rate incorporated 1 to 2 inches deep with a disk. The paraplow treatment was compared at two tillage depths. No-till was compared with two fertilizer application methods. Seven tillage-row spacing combinations were planted on each of three planting dates about 15 October, 1 November, and 15 November. Data were subjected to analyses of variance and means were separated using least significant differences at th 5% statistical probability level.

Each September plots were chiseled 6 to 8 in. deep with a double-gang chisel plow. The shanks on the front and rear tool bars were offset with 12-in. shank spacings. These plots were disked 3 to 4 in. deep and the soil was smoothed at planting with a do-all, an implement with a rolling cutter-bar and a drag-harrow. The paraplow is a reduced tillage implement which initially looks similar to a moldboard plow but lifts the soil vertically and causes minimum surface disturbance. The paraplow tillage treatment depths were 7 to 8 and 14 to 15 in. The soil surface was smoothed with a do-all before planting wheat in 8-in rows. The no-tillage wheat was planted in 8-in. rows with two fertilizer application methods: fall injected liquid N and surface applied N as granular urea.

Plot management in preparation for fall wheat planting involved mowing, applying fertilizer, and tillage. In late August of each year the whole study was mowed to a height of about 5 to 6 in. with a rotary mower. In mid-September of each year, 450 lb/acre of 0-20-20 (N-P_2O_5-K_2O) was applied surface broadcast before the tillage treatments chisel + disk and paraplow were applied. In early October, before planting wheat, granular urea fertilizer at 50 Ib N/acre was surface broadcast to all treatments except the no-tillage injected N treatment. The no-tillage injected N treatment received 50 lb N/acre as a liquid urea solution injected at planting with a Marliss no-till drill equipped with colters spaced 16 in. apart between wheat rows as one-pass operation. A solid core nozzle trailing each colter applied liquid N solution as a solid stream to the colter penetration depth of about 2 in. Another 80 lb N/acre of granular urea was surfaced broadcast to all wheat treatments in mid-February of each year.

Herbicides were used for weed control. Roundup at 1.5 lb ai/acre was applied as a burndown application on all no-tillage and paraplow treatments about 5 October of each year. Hoelon at 1 lb ai/acre was applied postemergence in the fall to all treatments for annual ryegrass control. In mid-February to mid-March one application of Harmony + surfactant at 0.025 lb ai/acre + 0.25% v/v was made to all treatments for winter annual broadleaf weed control. After wheat harvest in June, one application of 2,4-D Amine + surfactant at 0.5 lb ai/acre + 0.25% v/v was applied in early July and August for summer annual broadleaf weed control.

Table 1. Wheat cultivars and planting dates at the Pontotoc Branch Experiment Station, 1985-87.

Year	Planting Dates			Cultivar
1985	Oct. 18	Nov 6	Nov 20	Florida302
1986	Oct 17	Nov 1	Nov 17	Pioneer 2551
1987	Oct 25	Nov 3	Nov 16	Florida302

Each year three wheat plantings (Table 1) were made on about 15 October, 1 November, and 15 November. All 8-in. wheat row spacings were planted with a Marliss no-till drill. The 4-in. row spacing was planted with 1 conventional 4-in. Marliss drill. All row spacings were planted with 30 seeds per sq ft except the chisel + disk broadcast (B'cast) treatment. The chisel + disk broadcast treatment was seeded on the soil surface at 60 seeds per sq ft (2x rate) with the Marliss no-till drill. Seeds were incorporated with a disk. Wheat cultivars and planting dates for all 3 yr are listed in Table 1.

Field data was collected in mid-March and at maturity. Wheat population was determined in mid-March of each year. Stand counts were determined by randomly selecting one 8-in. linear sample per row of 6 randomly selected rows within a 10 ft wide plot. Plants were excavated from the soil, separated, and counted. These data were converted to plants per sq ft. At maturity, wheat plant height and spike date were collected. Wheat plant heights were determined by randomly selecting a site in each of 6 randomly selected rows. The first 3 consecutive plants at each site were measured from the soil surface to the top of the spikes. Wheat spike date were determined by randomly selecting an 8-in. linear sample in each of 6 randomly selected rows and counting the number of spikes per sample. The total number of spikes per 6 samples were averaged for each plot and converted to spikes per sq ft.

Wheat plots were harvested with a plot combine harvesting a 6- by 35-ft area on 16 June 1986, 28 May 1987, and 10 June 1988. Plot seed samples were weighed, and seed moisture and test weight were determined with a Dickey John electronic grain analysis computer (GACII). Wheat yields were adjusted to 13 percent seed moisture.

Results and Discussion

Wheat yields, averaged over treatments, ranged from 39 bu/acre in 1986 to 63 bu/acre in 1988. There was no planting date x system interaction. However, there was a planting date x year interaction (Table 2). The 1 November planting yields of 44 and 67 bu/acre in 1986 and 1988, respectively, were higher than the 15 October planting date both years. In 1987, however, there was no difference between 1 November and 15 October planting dates. The yield for the 15 November planting was significantly higher than 15 October in 1986 and significantly lower than 15 October in 1987 with no difference in 1988. The results indicated that about 1 November is the best planting date to maximize yield in North Mississippi.

Wheat yield response differed among production systems (Table 3) and interacted with years. The paraplow treatments with 8-in. rows produced yields equal to chisel + disk with 4-inch rows all three years. The paraplow 14 - to 15-in. depth of tillage did not yield more than paraplow 7- to 8-in. tillage

Table 2. Effect of wheat planting date on yield averaged over system at the Pontotoc Branch Experiment Station, 1986-88.

P. Dates	1986	1987	1988	AV
	bu/acre			
Oct 15	34	51	59	48
Nov 1	44	52	67	54
Nov 15	40	43	63	49
AV	39	49	63	

LSD 0.05 Year 5 LSD 0.05 Years within P dates 7
LSD 0.05 P. dates 5 LSD 0.05 P. dates within year 4

Table 3. Wheat yield response to production systems averaged over planting dates at the Pontotoc Branch Experiment Station, 1986-88.

Production System: Tillage	Row Spacing (in)	1986	1987	1988	AV
		Bu/acre			
Chisel + Disk	B'Cast	37	44	64	48
Chisel + Disk	4	42	53	68	54
Chisel + Disk	8	38	45	64	49
No-tillage*	8	38	48	58	48
No-tillage	8	38	48	57	48
Paraplow 7	8	42	51	65	53
Paraplow 14	8	41	51	65	52
AV		39	49	63	

*Fertilizer injected
LSD 0.05 Years 5 LSD 0.05 Years within production system 7
LSD 0.05 P. System 2 LSD 0.05 Production systems within year 4

depth. Although not always significant, both chisel + disk 4-in. row spacing and paraplow treatments with 8-in. wheat row spacing produced higher yield than chisel + disk broadcast seeding, chisel + disk 8-in. rows, and both no-tillage treatments. In contrast no-tillage produced yields equal to chisel + disk with 8-in. wheat row spacing in 1986 and 1987 but was lower than chisel + disk in 8-in. wheat row spacing in 1988. With no-tillage, both surface applied urea and urea injected as a liquid produced similar yields all three years.

Production system had no effect on plant height at maturity. However, planting date influenced plant height. In 1986 the 15 October planting was shorter in height than 1 November and 15 November planting dates. The 15 November planting was shorter in height than 15 October and 1 Novemberplanting in 1987 with no height differences in 1988.

Generally, plant population and number of spikes per sq ft were not affected by planting date and system. However, the chisel + disk 4-in. row spacing all three years had more plants per sq ft and spikes per sq ft than other systems on all planting dates.

Summary

The 1 November planting date for North Mississippi produced the highest yield 2 or 3 yrand had the highest 3 yr average for all 3 planting dates. The chisel + disk in 4-in. rows and both paraplow treatments had significantly higher yield than both no-tillage and chisel + disk with the 8-in. row spacings in 2 of 3 yr. These treatments also had the highest 3 yr average yield of all treatments. No-tillage in 8-in. rows and chisel + disk with a broadcast 2x seeding rate had significantly lower yields than all other treatments 2 of 3 yr and the lowest 3 yr average. Averaged over 3 yr, no-tillage wheat with 8-in. rows produced yield equal to conventional chisel + disk with both 8-in. rows and broadcast 2x seeding rate incorporated with a disk. Paraplow tillage depth of 7 to 8 in. was adequate to maximize wheat yield. Both paraplow 8-in. rows and chisel + disk 4-in. row treatments produced about 10% higher yield (3 yr average) than chisel + disk with 8-in rows.

The study indicated that the reduced tillage paraplow system not only has the advantage of reduced soil erosion potential but also enhanced wheat yields. The no-tillage system has the advantage of reduced soil erosion potential and yields were equivalent to the conventional chisel + disk production system. Studies need to be continued long-term on different soil types with full economic analysis in order to more fully assess the potential of these reduced tillage systems for wheat production in Mississippi.

Reseeding Potential of Crimson Clover in No-Till Corn

J.L. Myers and M.G. Wagger[1]

Introduction

In recent years, research and interest in the use of winter annual cover crops for various conservation tillage systems has received considerable attention due to environmental concerns and the rising cost of fertilizer nitrogen. Cover crops have been attributed with reducing soil erosion and weed pressure (4), as well as improving infiltration and retention of rainfall (5). In addition, leguminous cover crops may provide substantial quantities of biologically-fixed nitrogen (N) to summer crops such as corn and sorghum, making supplemental fertilizer nitrogen unneccessary or minimal (3,6,9,10).

Despite these beneficial qualities, the widespread acceptance of leguminous cover crops for conservation tillage production may depend on resolving a couple of management problems. First, the annual fall establishment of the legume is costly and may be unsuccessful if climatic conditions are not favorable. Based on current fertilizer N prices, the legume must provide at least 80 lb of N to offset establishment costs (7). Secondly, growth of winter annual legumes is most rapid in late spring, during which most of the dry matter and nitrogen production occurs. This rapid growth period

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generally coincides with optimal planting dates for corn, and may, in relatively dry springs, have a detrimental effect on corn seedling growth due to soil moisture depletion (2).

Crimson clover is well-adapted to the southeastern United states and demonstrates good reseeding ability (1). In the Piedmont region of North Carolina, corn is often grown continuously for silage and would therefore fit into a self-reseeding cover crop system. With these factors in mind, the objective of this research was to investigate the self-reseeding potential of crimson clover and its effects on corn yield compared to annual fall planting of crimson clover.

Materials and Methods

The experiment was conducted in 1987 and 1988 at the Upper Piedmont Research Station, Reidsville, NC. The soil type was a Pacolet sandy loam (clayey, kaolinitic, thermic, Typic Hapludult) and is representative of southern Piedmont soils.

Four cover crop treatments were evaluated with four fertilizer N rates in a 4x4 factorial randomized complete block design with four replications. The cover crop treatments consisted of 1) fallow, where there was no cover crop grown; 2) direct-seeded, planted each fall with complete burndown at corn planting; 3) early-reseeded, also burned down completely at corn planting but potentially with enough viable seed to ensure stand establishment in the fall; and 4) strip-reseeded, at corn planting 18" bands over the corn row were burned down with 2 0 left between each row to mature. Fertilizer N rates were 0, 45, 90, and 135 Ib/A, respectively.

Crimson clover ('Tibbee') was broadcast seeded at 15lb/A on September 22, 1986 to establish the experimental area. The various crimson clover treatments were accomplished with a lpt/A 2-4,D amine and 2pt/A Paraquat mixture at corn planting. Corn ('Funks 4522') was planted in May (5-14-87 and 5-9-88) at approximately 25,000 plants/A in 3 8 rows using a John Deere Max Emerge no-tillage planter. Residual weed control was provided with an herbicide mix of 1.5qt/A AAtrex and 2.5 qt/A Lasso surface broadcast at planting. The respective fertilizer N rates, as ammonium nitrate, were applied approximately 3 weeks after corn planting.

Crimson clover dry matter production and N concentration were determined on samples taken just prior to corn planting. Seed head samples were collected from representative plots at the same time and ten days later to determine percent germination and seed production. Corn grain yield (adjusted toa 15.5% moisture basis), along withcornearleafandgrain N concentration. were also measured.

Results and Discussion

Crimson clover dry matter production and N concentration just prior to corn planting in 1988 are shown in Table 1. Dry matter yields and N concentration were unaffected by N rate, however, cover crop management did have a significant effect on both parameters (p >.001). Early-reseeded and strip-reseeded treatments produced similar dry matter yields. In contrast, the direct-seeded treatment averaged only 26% of the biomass produced in the reseeding treatments. The fall of 1987 was very dry after planting the direct-seeded treatment, resulting in poor establishment of crimson clover. Greater seed quantities (data not presented) available with the reseeding treatments may have provided more flexibility with regard to time of germination. If one group of germinating seeds failed to coincide with adequate rainfall there would be more to follow later, as a certain percentage of clover seeds break dormancy on a gradual basis (8). The lower N concentrations observed for the reseeding treatments compared with the direct-seeded treatment reflect a dilution effect due to the nearly four-fold increase in dry matter production.

Germination tests indicated only a small percentage of seeds were viable at the time of crimson clover burndown and corn planting (Table 2). Ten days later, however, seed viability in the strip-reseeded plots had increased dramatically. Seed heads from the early-reseeded plots had already fallen from the plants, consequently samples could not be obtained. Nevertheless, those seeds appeared to mature enough after the complete burndown to produce viable seeds and adequate stand the following fall. Alternately, the 20% determined viable on the earlier sampling date may have been sufficient to develop a uniform stand, as was observed

Table 1. Dry matter production and N concentration of crimson clover as affected by N rate and clover management in 1988.

Clover mgt.	N rate (lb/A) 0	45	90	135	Cl. mgt. mean
		Dry matter (lb/A)			
Direct-seeded	2425	2789	1077	1448	1935
Early-reseeded	8340	7640	6103	8264	7587
Strip-reseeded	7135	5258	7105	7839	6834
N rate mean	5967	5229	4762	5850	
Treatment effects					
Cover management (C)		**			
N rate (N)		NS			
C X N		NS			
		N concentration (%)			
Direct-seeded	2.48	2.45	2.54	2.58	2.51
Early-reseeded	1.97	2.22	2.31	2.11	2.15
Strip-reseeded	2.08	2.42	2.27	2.27	2.26
N rate mean	2.17	2.36	2.38	2.32	
Treatment effects					
Cover management (C)		**			
N rate (N)		NS			
C X N		NS			

**Significant at the 0.01% level of probability
NS Not significant

Table 2. Effect of maturity on seed viability of crimson clover.

Sampling date	% germ.	% im.	% dor.
1987			
14 May (planting)	20	74	6
24 May	*66*	2	32
1988			
9 May (planting)	I	99	0
20 May	*52*	16	32

in 1988. At the later sampling date the percentage of dormant seeds increased, providing a more flexible window of germination time.

Corn grain yields were not significantly affected by fertlizer N rate either year (Table 3). These results are not surprising given the relatively dry growing season conditions that prevailed at this site in 1987 and 1988. Under limited rainfall conditions, corn uptake of N is often restricted. Grain yield, however, was influenced by the presence of a cover crop, indicating a mulch effect both years. Under a supposedly non-limiting N statue (i.e. 135 lb/A), orthogonal contrasts revealed significantly higher grain yields for all crimson clover treatments compared to the fallow system. The positive effects of the mulch were readily apparant in the field, as plant water stress symptoms were commonly observed in the fallow treatment.

Ear leaf nitrogen concentrations varied significantly between N rates, but as corn growth proceeded and soil moisture remained limiting, differences became obscured so that grain and stover nitrogen concentrations were unaffected by N rates (data not presented).

In 1988, the early-reseeding and strip-reseeded resulted in higher grain yields than the direct-seeded treatments. The failure in 1988 of the direct-seeded treatment to perform as well as the other two crimson clover treatments was due to its poor establishment the previous fall. Given the dry weather that prevailed both years, these results also suggest that N from crimson clover was sufficient for the yield potential that existed.

Table 3. Influence of crimson clover management and N rate on corn grain yield.

	N rate (lb/A)							
	0	45	90	135	0	45	90	135
	bu/A							
Clover mgt.	**1987**				**1988**			
Direct-seeded	60†	62	71	65	71	75	***64***	67
Early-reseeded	---	---	---	---	98	98	116	107
Strip-reseeded	---	---	---	---	108	**113**	119	117
Fallow	43	43	50	**25**	52	59	64	44
Treatment effects								
Cover mgt. (C)	**				**			
N rate (N)	NS				NS			
C X N	NS				NS			

[1]Mean values for all crimson clover treatments since reseeding treatments were not fully established until the second year.

**Significant at the 0.01% level of probability.

NS Not significant.

Conclusions

During years of limited rainfall, a crimson clover cover crop can be beneficial to yield of corn by providing a mulch which conserves oil moisture and enhances infiltration. Allowing crimson clover to mature before chemical burndown and corn planting, or leaving strips of crimson clover between corn rows to produce seed, are both potential methods for cutting seed costs and reducing the risk of cover crop establishment. Under extremely dry summer conditions, as occurred in this study, there may be no difference in these two reseeding methods, However, if rainfall is limited at corn planting time, benefit may be derived from killing crimson clover early in strips. This practice could minimize competition for soil moisture with the corn seedlings and yet produce sufficient seed for fall reestablishment of crimson clover.

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Seeding Aechynomene in Bahiagrass Sod

R.S. Kalmbacher[1]

Introduction

If a Florida rancher wants to grow a grass and legume together for summer pasture, it will be bahiagrass and aeschynomene, respectively. It's certain that bahiagrass will always be available in the pasture, but aeschynomene is not so dependable. The problem is that it is an annual and must start from seed each year. Just when and how much aeschynomene you get depends on many factors, the most important of which the rancher has little or no control over. Growing aeschynomene-compared to nitrogen fertilization or bahiagrass-involves risk, but the risk can be minimized. The purpose of this presentation is to review the recommended steps for establishing aeschynomene in bahiagrass.

Steps for Establishment

1. **Site selection** is a major consideration, paticularly soil drainage. Aeschynomene grows well on soils with poor internal drainage, but soils with surface drainage are needed. Water can not stand on the soil surface for several days. This is especially important during establishment of aeschynomene. In contrast, avoid excessively drained soils (sand ridges) where establishing aeschynomene would be very difficult. Also select soils with better natural fertility. Most ranchers have recognized one or more fields where "the grass grows better," and these should be seeded with aeschynomene rather than the field with poorer fertility.

2. **Liming** before seeding is important because the grower needs to have the site in a condition that is favorable for aeschynomene growth. Lime as needed to bring the soil pH up to 5.5 to 6.5, and if these soil pH values are obtained, then plant calcium needs will also be met. It may be good practice to apply dolomitic lime to supply magnesium.

3. **Fertilization** should be delayed until a successful seedling stand is established. Hold-off fertilization at the time of drilling or when disking to regenerate aeschynomene. After seedlings are two to three weeks old, fertilize with 300 Ibs/A of an 0-10-20 fertilizer. Micronutrients deficiencies will normally not be a problem on pasture if they have been applied in the past. A safe approach would be to apply 20 1b/A of a mixture such as F 503[2].

4. **Seeding date** must be chosen carefully. The greatest reason for stand failure of aeschynomene is inadequate soil moisture at or shortly after seeding. I emphasize that **seeding date and it's relation to soil water is the most critical factor in establishing aeschynomene.** The problem occurs when there is adequate moisture for germination, but not enough soil water to carry legumes from one shower to next. One way to overcome this is to seed or lightly disk to stimulate aeschynomene regeneration when the chance for continuous good soil water is greatest.

Seventeen seedings of aeschynomene were made at the Ona AREC in south central Florida from May to late June 1981 to 1985, and six of these seedings were failures because of insufficient water. Failures due to drought always followed abnormally dry February to May periods when less than the average 11 inches of rain fell. Even with 1 inch of rain on the day of seeding (drilling), the seedbed dried out faster than the seedlings could establish. When there is a good reserve of soil moisture at seeding; soil dries more slowly, giving aeschynomene longer to establish, thus seedlings are larger and have a better chance of survival if drying occurs.

The six seedings that failed in the 5year Ona AREC trial were all May seedings. By waiting until after June 1st the chance of rain is better. By using Quincy data (41 yr averages) as an example for north Florida, the chance of no rain in the first week of June is 9%; the chance of 0.5 inch or more is 66%; the chance of 1.0 inch or more is 45%. Probabilities of rain improve through June which increase the chance of stand success. In most cases it is best to seed after June 1st, especially after a dry winter and spring.

5. **Seeding rates** should be slightly higher when seeding into sod. In a prepared seedbed use de-hulled (scarified) aeschynomene seed at 5 lb/A, but 6 to 8 lb are recommended for bahiagrass sod-seeding. Higher rates are recommended because of the great seedling losses from insects, snails, drought, disease, etc. For example, when aeschynomene was seeded in June 6 lb/A in a grazed sod, there were 11 seedlings/ft^2 at 8 days after seeding; 9 seedlings/ft^2 after 15 days and 5 seedlings/ft^2 after 31 days. By October the number averaged slightly greater than 3 seedlings/ft^2, which was a dense stand.

When seedings are made before June 1st or on a seedbed that tends to be dry, seed 25 lb/A of non-hulled seed. Again this rate is higher than the 10 lb/A recommended for prepared seedbeds. Germination percentage is usually 1 to 10% on non-hulled seed, but the hard-seed percentage can range from 40 to 70%. If conditions are good, a stand should result from easily germinated seed, but if conditions for germination are poor or if the initial stand fails, a reserve seed source is available from the hard seed. Mixing dehulled with non-hulled seeded (viz. 1:4 ratio) has been satisfactory.

6. **Inoculate seed** with fresh *Rhizobium* bacteria (cowpea group) that are specific for aeschynomene the first time the crop is seeded in a field where it has never been grown. Covering the seed helps assure longevity of bacteria. Once aeschynomene has been grown on a field, there is not reason to re-inoculate.

7. **Manage bahiagrass before seeding aeschynomene** to enhance success. In order to minimize competition problems for establishing aeschynomene, no nitrogen (N) should

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[2]F-503 is an oxide form containing 3.0% B, 3.0% Cu. 18.0% Fe, 7.5%Mn. 0.2Mo, and 7.0%

be applied to the bahiagrass after the fall preceding spring seeding of aeschynomene. Remove excess bahiagrass cover before seeding to assure that emerging aeschynomene seedlings have adequate light. A dense canopy of 8 to 12 inch tall bahiagrass reduces the amount of light reaching seedings and this results in poorer stands of aeschynomene. When aeschynomene was seeded into bahiagrass without controlling canopy height. an average of 36% of the total sunlight was able to get through the grass-leaf cover during the first 4 weeks after seeding. Bahiagrass that had been disked or grazed to 3 inch height prior to seeding allowed an average of 60% of the light to reach the seedings. Yield of aeschynomene over a 3-year trial period averaged 2,050 lb/A where bahiagrass was grazed before and during aeschynomene developement, but yield was 1200 lb/A where aeschynomene was seeded into ungrazed bahiagrass.

Grazing is a practical method of removing excessive bahiagrass. Concentrate cattle in late winter-early spring to graze bahiagrass to 2 to 3 inches. Grazing has an advantage over methods of canopy removal like mowing because repeated defoliation reduces the vigor of bahiagrass such that it will not regrow rapidly after cattle are removed. Control of cattle after seeding will be discussed shortly.

Burning can be useful for establishing aeschynomene. When excess bahiagrass is burned-off after grazing in late winter and spring, aeschynomene seed germination and seedling vigor is enchanced. especially when bahiagrass regrowth is controlled by grazing. However, the practicality of this is limited because there is usually not enough fuel after winter grazing to carry a fire. Unless burning takes place before spring green-up, the pasturc will not burn well.

Research has shown good stands of aeschynomene can be obtained when bahiagrass is burned before seeding aeschynomene. The amount of aeschynomene and aeschyoment-bahiagrass mixture quality that resulted from burning and seeding were similar to yield and quality of grazing bahiagrass and seeding aeschynomene.

Herbicides applied for the specific purpose of controlling bahiagrass growth are not recommended. Numerous herbicides have been tested for establishing summer legumes, and there are herbicides that will stop bahiagrass growth, but a large grass canoy (dead or alive) can result in excessive shade, and yields are not always improved. The canopy must be removed, and then legume yield can be improved with herbicides which limit grass growth. However, cost is a limiting factor that weighs against the use of herbicides for canopy control.

Disking is an effective method of canopy removal. but establishment of aeschynomene is often poorer than use of grazing to remove excess grass. The reason is loss of seedbed moisture. Even with a light disking, which is all that is necessary, the soil surface is disturbed and exposed to the sun, drying the surface.

8. **Method of seeding** is of lesser importance if a good job of controlling grass competition and adequate water and fertility are available. Several commercially available sod-seeding drills have all proved to be good, which makes machine selection a personal and economic matter. Regardless of the drill used. place aeschynomene seed at 1/2 to 3/4 inch below the soil surface into the moisture. Seeding too deep in Florida's dry. sandy soils is much less of a hazard than seeding too shallow.

Disking the soil and broadcasting seed, followed by culti-packing does not have consistent success unless irrigation is provided. Disking removes the grass canopy, but results in poor seedbed moisture. Yields of aeschynomene seeded by disking and broadcasting can be similar to aeschynomene yields from drilling when continued rains occur after seeding aeschynomene. Better seed-to-soil contact through the use of a drill results in better stands of non-irrigated legumes.

9. **Manage bahiagrass after seedling establishment** to promote good stands. graze after legume emergence to keep bahiagrass about 3 inches tall. Remove cattle from the pasture when seedlings reach about 2 inches tall, so that they do not graze the tops of the acschynomene seedings. Allow grazing to resume when aeschynomene is 18 inches tall.

Aeschynomene should reestablish itself each year once a seed source is built up in the soil. The same steps must be followed to allow aeschynomene to voluntarily reestablish as when establishing the crop initially. Removal of hahiagrass canopy is important. and this can be accomplished by burning and/or grazing. Light disking can also be used effectively. but this must be done at the time when seeding is recommended to allow greater chance of adequate seedbed moisture.

Summary

Remember the three most important steps to improve establishment success: site selection; seeding date, and bahiagrass canopy control. Following all nine steps will help assure successful establishment of aeschynomene. Additional assistance and advice from county extension agents or the forage extension specialists at the IFAS Research Centers are available.

Initial Development of Early Blooming Annual Cool Season Legumes for Use in Conservation Tillage

C.M. Owsley, M.S. Kirkland, and E.D. Surrency[1]

Introduction

Earlier in this century legume cover crops were in wide use. Farmers utilized various legumes for green manure crops throughout the Southeastern United States. These crops provided excellent cover for the prevention of soil erosion and they also produced valuable nitrogen for subsequent crops. With the popularity of commercial fertilizers, the use of legumes for green manure crops declined. However, agricultural scientists have again begun to do extensive work with cool season legumes for use on southern farms in conservation tillage systems.

Much of the beneficial nitrogen produced by legumes is assimilated by the time most cool season annual legumes flower. Therefore, it would be advantageous to develop various legume cultivars that display the early blooming characteristics, since this would allow for flexibility in conservation tillage systems. With this in mind, the Americus Plant Materials Center has begun a program to develop new early blooming cool season annual legume cultivars for conservation tillage use.

Legumes Used in Conservation Tillage Work

The results of a study conducted in the Piedmont of Georgia suggest that a double cropping system of reseeding crimson clover *(Trifolium incarnatum* L.) and grain sorghum *(Sorghum bicolor* L.) Moench) provided sufficient nitrogen for maximum sorghum grain yield (Touchton, et al., 1982).

Another study in Georgia used crimson clover, *(T. incarnatum* L.), subterranean clover *(Trifolium subtarraneum* L.), hairy vetch *(Vicia villosa* Roth.) and common vetch *(Vicia sativa* L.) in a grain sorghum *S. bicolor* (L.) Moench) no-till system (Hargrove, 1986).

Initial Screening of Legumes

In fall 1983, the Americus Plant Materials Center started to assemble and evaluate collections of cool season annual legumes, for use as cover crops in conservation tillage systems. The center has used the initial evaluation block located on Orangeburg sandy loam at Americus, Georgia to screen approximately 1,000 cool season annual legume accessions. These legumes have included germplasm from several genera including *Lathyrus, Trijolium, Vicia* and *Medicago.* They were assembled from foreign, as well as naturalized populations. All foreign accessions came through the plant introduction system. The naturalized legumes were collected and processed by Soil Conservation Service personnel in the Southeastern United States. Each accession (a documented and numbered legume) was evaluated for adaptability, growth, vigor, winter hardiness, stand, reseeding ability, flowering date, seed production, disease resistance and insect resistance.

Early Blooming Hairy Vetch

In 1987, two early blooming hairy vetch *(V. villosa* Roth.) accessions, 9053961 and 9052057 were observed growing in the Americus Plant Materials Center initial evaluation block. Seed from these accessions were harvested on and September 18, 1987 were planted to two separate small increase blocks. On April 6, 1988 the 9053961 block was rogued except for 34 lines (plants), which were selected for vigor and mid-bloom Characteristics. On May 13, 1988 this seed was harvested according to individual lines. The 9052057 accession displayed a delay in blooming and was discarded.

On September 28, 1988 seedlings from each of the 34 selected 9053961 lines were planted to an evaluation block. The block was divided into four replications. Each line was randomly planted to each replication in a six foot by six foot spacing pattern with four seedlings per line per replication. Therefore the block consisted of 544 space planted individuals. Replacement plants were added when needed. On March 22, 1989 the entire block was evaluated for early bloom, uniformity and vigor. This evaluation resulted in the selection of the most vigorous, early blooming plants in the test. This information was used to rank all lines according to their selection results. Then 34 plants were selected that belonged to the highest ranked lines. All other plants were removed. Seed from these selected plants will be harvested and used in a similar evaluation in 1990.

Early Blooming Crimson Clover

In 1987, eleven accessions of early blooming crimson clover (*T. incarnatum* L.), were observed in the initial evaluation block at the Americus Plant Materials Center. Seed was collected from these accessions and equally bulked. On October 19, 1987, 670 seedlings from these seeds were space planted to a three foot by three foot grid system. On March 31, 1988 the 670 plants were rogued for vigor and early bloom characteristics. Two hundred plants were selected that displayed the desired phenotypic characteristics. On May 4, 1988 seed from these 200 plants were collected individually.

On October 24, 1988 seedlings from each of the 200 selected plants (lines) were planted to a stratified grid at the Americus Plant Materials Center. Each of the 200 lines were randomly planted to five replications within the grid. This produced a total of 1,000 individual plants on a two foot by two foot spacing within the rectangular grid. The grid consisted of 40 blocks with each block containing 25 plants. Rows of Tibbee Crimson Clover seedlings were space planted around the grid for comparison and competition. Replacement plants were added when individuals died.

On February 14, 1989 five plants from each 25 plant block were selected for early bloom and vigor characteristics. All other plants in the grid were removed. After cross-pollination has occurred, seed from each of the selekted

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plants will be harvested. This will result in 200 lines for similar evaluation in 1990.

Future Development for Conservation Tillage

After one or two more selection cycles, the Americus Plant Materials Center hopes to develop new crimson clover and hairy vetch cultivars that will bloom early and fit into conservation tillage systems in the Southeastern United States. Seed will be provided to the Soil Conservation Service, Agricultural Research Service, universities and Agricultural Experiment Stations for conservation tillage experimentation.

Acknowledgements

The Americus Plant Materials Center gratefully acknowledges the guidance provided by Dr. Joe Bouton of the University of Georgia, in establishing the development plan of these legumes.

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Comparative Effects of Tillage on Winter Annual Forage Production

David Lang[1]

Introduction

Production of winter annuals in the Southeast provides a valuable source of high quality forage (1,6). Production practices normally include disking of land summer fallowed and cultipacking to facilitate direct seeding (9). Altematively, a winter annual may be overseeded into an existing sod (5,10). Winter annual production into a prepared seedbed will generally provide earlier grazing and will tend to yield more compared to overseeding (3, 4,10, 11, 13).

Sod-buster provisions of the 1985 Farm Bill may limit the degree of disking permitted for winter annual seedbed preparation (12). Seeding directly into the residue of the previous winter annual plus summer annual weeds consisting mainly of crabgrass *(Digitara sanguinalis)* and broadleaf signalgrass *(Bracharia platyphylla)* may provide a suitable practice. The objective of this study was to compare yield of winter annuals planted with and without tillage into a crabgrass residue.

Materials and Methods

Summer annual weed growth was promoted by irrigation in June. 1988. The dominant species was crabgrass (Digitara *sanguinalis).* Weed growth was clipped in July and Aug. but not removed. On 14 Sept. 1988 plots were clipped and herbage removed and one-third of the plots were roto-tilled with a Troy-hilt rear tine implement. Paraquat was applied 26 Sept. 1988 to another third of the plots while another third was left unsprayed and untilled. 'Walken' oats *(Avena sativa).* 'Marshall' ryegrass *(Lolium multiflorum),* Tyfon *(Brassica rapa* x *B. pekinensis)* and a combination of oats and tyfon were seeded on 27 Sept. 1989 with a Tye Pasture Pleaser no-till drill. Yield evaluations were made on *5* Dcc. 1988 and 10Mar. 1989. An adjacent field was disked and fallowed throughout the summer for a small grain for forage trial which included 'Walken' oats and 'Marshall' ryegrass. The clean-till plots were seeded on 10 Oct. 1988 and harvested on 19 Dec. 1988, 18 Jan. 1989 and 13 Mar. 1989.

Results and Discussion

Soil fertility levels were generally adequate in both experiments (Table l). Abundant rainfall and very favorable temperatures occurred during the time of the experiments (Table 2). Over 3 inches of rain fell during the week after seeding the no-till test and over 2 inches fell following seeding of the clean till test. The lowest temperature of the period occurred 10 Feb. 1989 at 18°F and 17°F on 24 Feb. 1989. Only minor frost damage was observed on any of the species tested. Annuals seeded into crabgrass had lower stands than those seeded into rototilled plots (Table 3). Due to the warm weather from planting until first frost 7 Nov. 1988, crabgrass continued to grow and comprised 25% of the untreated soil plots. This resulted in a higher dry matter percentage on 5 Dec. harvest and indicated that crabgrass contributed considerably to the yield of sod-seeded plots.

Yield of annuals on 10 Mar. were higher in the rototill or crabgrass with paraquat plots compared with untreated crabgrass plots (Table 4). Other researchers have generally found that winter annuals growing in a prepared seedbed yield almost twice as much as sod-seeded annuals and provide grazing 2-4 months earlier (3.4). Winter annuals seeded into summer annual residues, however, may not be as severely affected, compared with seeding into a permanent sod. Ryegrass seeded into broadleaf signalgrass residues were able to be harvested in Dec. and Feb. while ryegrass seeded into bermudagrass sod could not be harvested until March (2).

Table 1. Soil fertility levels of no-till and clean till experiments.

	pH	P	K	Ca	Mg
		-- Extractable	Nutrient	levels	(lbs/A) --
Clean Till	5.1	161 H +	88 L	2918 H+	78 M
No Till	5.8	111 H	170 H	2672	80 M

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Table 2. Weekly Weather from Sept., 1988 to Mar., 1989 at Mississippi State, MS.

Week Ending	Air Temperature Max	Air Temperature Min	Rainfall	Date of Minimum Below Freezing
	---------°F	---------	-inches.	
Sept. 7	80	61	1.62	
Sept. 14	86	79	0.27	
Sept. 21	86	72	2.30	
Sept. 28	83	66	0.24	
Oct. 5	63	57	3.74	
Oct. 12	68	44	0.00	
Oct. 19	74	45	0.81	
Oct. 26	67	46	1.25	
Nov. 2	66	47	0.24	
Nov. 9	76	50	0.52	32°F on 11/7
Nov. 16	70	48	1.16	
Nov. 23	62	36	2.25	32°F on 11/18
Nov. 30	63	37	1.14	27°F on 11/29
Dec. 7	59	29	0.00	24°F on 12/6
Dec. 14	50	31	0.23	29°F on 12/10
Dec. 21	55	34	0.04	21°F on 12/18
Dec. 28	66	42	1.42	30°F on 12/28
Jan. 4	54	37	2.88	25°F on 12/29
Jan. 11	60	42	2.09	32°F on 1/5
Jan. 18	54	35	5.17	26°F on 1/17
Jan. 25	60	34	0.02	25°F on 1/22
Feb. 1	66	42	1.16	32°F on 1/27
Feb. 8	45	32	0.87	21°F on 2/7
Feb. 15	64	39	0.03	18°F on 2/10
Feb. 22	51	41	2.41	30°F on 2/22
Mar. 1	49	31	3.05	17°F on 2/24
Mar. 8	52	37	0.79	30°F on 3/7
Mar. 15	77	45	0.00	30°F on 3/9
Mar. 22	69	44	1.75	
Mar. 28	69	49	1.40	32°F on 3/28

Table 3. Effect of tillage on % stand of winter annuals established as of 5 Dec. 1988.

Tillage[1]	Stand	D. M.	Crabgrass[2]
	%	%	-lb/A-
Rototill	96 A	13.9 B	1 B
Paraquat	96 A	14.3 B	48 B
Residue	84 B	26.6 A	310 A
$LSD_{.05}$	8	3.7	115

[1]Means followed by the same letter within each column were not significantly different.

[2]Crabgrass yields were estimated visually

Table 5 presents yield date for each species tested. Yield reductions were observed at the first harvest in the crabgrass plots, but yields were equivalent in each tillage treatment on 5 Dec. due to the growth of crabgrass (Table 3). Yields on 10 Mar. reflected an advantage for the rototilled plots, compared with either crabgrass plot, particularly with ryegrass or oats. Oats seeded into paraquat treated crabgrass yielded similarly to oats seeded in rototilled plots while ryegrass grew best when seeded into rototilled plots.

Oats and ryegrass yielded twice as much in the clean-till

Table 4. Overall effect of tillage on yield of winter annuals.

Tillage	Forage Yield Dec. 5	Forage Yield March 10
	------lbs/A	------
Rototill	1119	984 A
Paraquat of Crabgrass residue	1177	803 A
Crabgrass residue	1185	586 B
$LSD_{.05}$	NS	185

Means followed by the same letter within each column were not significantly different.

Table 5. Effect of tillage on various winter annuals.

Winter Annual	Tillage	Forage Yield Dec. 5	Forage Yield March 10
		------- lbs/A	-------
Oats	Rototill	1108	1372
	Paraquat	1044	1281
	Residue	1333	793
Ryegrass	Rototill	988	1445
	Paraquat	968	935
	Residue	778	692
Oats & Tyfon	Rototill	1152	718
	Paraquat	1214	679
	Residue	1598	551
Tyfon	Rototill	1228	400
	Paraquat	1076	316
	Residue	1071	307
Overall $LSD_{.05}$		243	213
Comparisons:			
Rototill vs. sod		NS	***
Paraquat vs. Residue		NS	**

Table 6. Yield of Oats and Ryegrass seeded into a prepared seedbed compared with No-Till.

	Walken Oats Dec.	Walken Oats Jan.	Walken Oats Mar.	Marshall Ryegrass Dec.	Marshall Ryegrass Jan.	Marshall Ryegrass Mar.
	------------	------------	------ lbs/A	------	------------	------------
Clean Till[1]	1375	1925	2231	2079	2069	2267
No-Till[2]	1044	0	1281	968	0	935

[1]Clean Till had 500 lbs 13-13-13 at seeding.

[2]No-Till had 500 lbs 13-13-13 at seeding plus 50 lbs N as Ammonium Nitrate on 11/12/88.

(summer fallow) plots compared with even the rototilled plots in the no-till experiment (Table 6). The rototilled plots contained decaying residue of crabgrass that may have released an inhibiting factor into the soil. Many possibilities exist including nitrogen deficiency due to microbial tie up, oxygen deficiency due to microbial decay, or release of toxins during decay (7.8). Any or all of these of factors may be adversely affecting the growth of no-till seeded winter annual forage crops.

Establishment of winter annuals without tillage offers the opportunity to extend the grazing season of warm season permanent sods. Limitations exist, however, and each needs to be understood in order to be alleviated. Once these limiting factors are understood then cultural practices can be recommended and information vital to plant breeders can be used to improve winter annual forage production.

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Wheat Forage Response to Tillage and Sulfur Applications

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Introduction

Crop responses to applied sulfur are expected on deep sandy soils such as those found in the coastal plain region of the southeastern United States. Surface horizons of sandy coastal plain soils have low adsorption capacities for sulfate-sulfur and typically have low levels of extractable sulfate-sulfur (Mitchell and Blue, 1981; Neller, 1959; Rabufetti and Kamprath, 1977; Reneau and Hawkins, 1980; Rhue and Kamprath, 1973). A small adsorption capacity for sulfate-sulfur will result in limited residual effects of applied sulfur if leaching is occurring (Rhue and Kamprath, 1973).

Yield responses to applied sulfur have been reported for row and forage crops grown in the Southeast (Jordan, 1964; Rabuffetti and Kamprath, 1977; Reneau and Hawkins, 1980; Jones et al., 1982; Mitchell and Blue, 1989; Suarez and Jones, 1982; Oates and Kamprath, 1985; Thompson and Neller, 1963; Woodhouse, 1969). Sulfur fertilization has been shown to increase forage yields by as much as 50% under sulfur limiting conditions (Walker et al., 1956; Rees et al., 1974; Jones et al., 1982). In New Zealand, an annual application of 20 pounds of sulfur per acre is needed for adequate pasture growth (Adams, 1973). The current recommendation for sulfur on all crops in Alabama is 10 pounds per acre per year (Cope et al., 1983).

Research in the southeastern United States has shown that deep tillage is necessary to optimize wheat yields (Hargrove and Hardcastle, 1984, Karlen and Gooden, 1987; Sharpe et al., 1988; Touchton and Johnson, 1982). Root growth and distribution in many of these soils is restricted by traffic pans. Oates and Kamprath (1985) concluded that sulfur deficiency on wheat is likely to occur in soils that have a sandy surface layer and a tillage pan that restricts root growth into the subsoil. The objectives of this study were to determine the effects of tillage on wheat forage yields and evaluate wheat forage response to nitrogen and sulfur under conventional and reduced tillage systems.

Materials and Methods

Field studies were initiated in the fall of 1986 on Benndale (coarse-loamy, siliceous, thermic, Typic Paleudult) and Dothan (fine-loamy, siliceous, thermic, Plinthic Paleudult) soils and this report includes initial yield data from the first two years of this three year study. Both soils have sandy textures and are located in the coastal plain region of Alabama (Table I).

Treatments included two methods of tillage, two nitrogen rates. five rates of sulfur and two times of sulfur application. Tillage treatments were I) turn-disk prior to planting and 2) disk only prior to planting. The soil was turned with a moldboard plow at a depth of 8 to 10 inches. On the Dothan soil the entire experimental area received one pass with a field cultivator just prior to planting. Nitrogen rates were 120 and I80 pounds per acre. Sulfur rates were 0, 10, 20, 40, and 80 pounds per acre. Times of sulfurapplication were; I) prior to planting (fall) and 2) top dressing in early February (spring). The experiment was a split plot design with 4 replications. Tillage methods were the whole plots. Nitrogen rates, sulfur rates and time of sulfur application were the split-plots.

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 Funded in part by the Florida Institute of Phosphate Research.

Table 1. Initial chemical properties of the Dothan fine sandy loam and Benndale fine sandy loam soils receiving annual rates of phosphogypsum.

Location	Soil Series	Soil Depth	SO_4-S#	pH	Ca	K_20	Mg	P_20_5
					Extractable Nutrients&			
		inches	pm		---pounds/acre---			
Brewton	Benndale	0 to 10	6.1	6.2	637	58	72	60
Brewton	Benndale	10 to 20	16.3	5.2	250	46	56	4
Headland	Dothan	0 to 10	9.6	6.5	690	87	136	59
Headland	Dothan	10 to 20	14.5	5.8	290	40	57	3

#Extracted with a calcium phosphate solution.
&Extracted with Mehlick I (dilute double acid) extractant

Experimental areas were treated with limestone, potassium and phosphorus according to soil test. Wheat was planted in October or November each year. The fall applications of sulfur and half of the nitrogen were broadcast prior to planting. Spring applications of sulfur and the remaining nitrogen were broadcast in February. Sulfur was applied as phosphogypsum (15.3% sulfur) which is a by-product of the phosphate fertilizer industry. Wheat forage yields were determined by harvesting a strip in each plot as needed.

Results and Discussion

Total wheat forage yield data from the Benndale soil are summarized in Tables 2 and 3. During the two years of the study the conventional tillage system averaged 13.8% higher yields than the reduced tillage system when yields were averaged over all sulfur and nitrogen rates. However, differences due to tillage were not statistically significant. As expected, forage yields increased as the nitrogen rate was increased from 120 to 180 pounds per acre. Forage yields were also affected by the rate of sulfur and the time of sulfur application during both years of the study. In 1986-1987 (Table 2) yields were increased by as much as 13% by the application of sulfur. Applying sulfur in the spring increased forage yields by an average of 8% over the fall application. Similar trends were observed in 1987-1988 (Table 3).

Forage yields on the Dothan soil are presented in Table 4 and Table 5. In both years higher yields were obtained under conventional tillage ($P < 0.10$). The conventional tillage system produced an average of 27.5% more forage as compared to the reduced tillage system. Yield responses were obtained to added nitrogen and sulfur under both tillage systems. Forage yields were increased by as much as 16% by the addition of sulfur. Tillage effects were not eliminated by applying higher rates of sulfur and nitrogen. Forage yields on the Dothan soil were not affected by the time of sulfur application in 1986-1987 (Table 4). In 1987-1988 (Table 5) higher yields were obtained when sulfur was applied in the fall.

Table 2. Total wheat forage yields (lbs/acre) during the 1986-1987 growing season on a Benndale soil.

Time#	0	10	20	40	80	x
	S rate (lbs/acre)					
	120 lbs N/acre					
Fall	2030	2226	2143	2424	2296	2224
Spring	2030	2604	2416	2691	2761	2500
	180 lbs N/acre					
Fall	2378	2488	2639	2651	2496	2530
Spring	2378	2787	2568	2833	2737	2660

Test of significant effects

Tillage	NS
Nitrogen Rate	$P < 0.01$
Sulfur Rate	$P < 0.01$
Time	$P < 0.01$

#Time of sulfur application.

Table 3. Total wheat forage yields (Ibdacre) during the 1987-1988 growing season on a Benndale soil.

Time#	0	10	20	40	80	x
	S rate (Ibdacre)					
	120 lbs N/acre					
Fall	3975	4046	3777	4179	4347	4065
Spring	3975	4301	4555	4372	4232	4287
	180 lbs N/acre					
Fall	4295	4604	4940	4711	4592	4628
Spring	4295	4694	4702	5064	4820	4715

Test of significant effects

Tillage	NS
Nitrogen Rate	$P < 0.01$
Sulfur Rate	$P < 0.05$
Time	$P < 0.10$

#Time of sulfur application

Table 4. Total wheat forage yields (lbs/acre) during the 1987-1988 growing season on a Dothan soil.

N Rate (lbs/acre)	0	10	20	40	80	x
	Conventional Tillage					
	S rate (lbs/acre)					
	Conventional Tillage					
120	2386	2829	2614	2961	2837	2725
180	3702	3538	3054	3671	3767	3546
	Reduced Tillage					
120	2132	2103	2129	2474	2446	2257
180	2521	2921	2938	3030	3003	2883

Test of significant effects

Tillage	$P < 0.01$
Nitrogen Rate	$P < 0.01$
Sulfur Rate	$P < 0.01$
Time	NS

Table 5. Total wheat forage yields (lbs/acre) during the 1987-1988 growing season on a Dothan soil.

N Rate (lbs/acre)	Time#	S rate (lbs/acre) 0	10	20	40	80	x
Conventional Tillage							
120	Fall	2473	2550	2703	2838	2710	2655
120	Spring	2473	2416	2638	2838	2629	2599
180	Fall	2713	3655	3096	3174	3543	3236
I80	Spring	2713	2868	3096	2965	3073	2943
Reduced Tillage							
I20	Fall	1651	2052	2073	2064	1860	1940
120	Spring	1651	2081	2098	1988	1884	1940
180	Fall	2162	2546	2468	2461	2514	2431
180	Spring	2162	2321	2229	2520	2225	2291

Test of significant effects

Tillage	$p < 0.10$
Nitrogen	$P < 0.01$
Sulfur Rates	$P < 0.01$
Time	$p < 0.01$

#Time of sulfur application.

Conclusions

Wheat forage yields were affected by tillage on one of two sandy coastal plain soils. On a Dothan soil wheat forage yields were higher under a conventional tillage system as compared to a reduced tillage system. Yield responses were obtained to nitrogen and sulfur at both locations. Responses were obtained to nitrogen and sulfur at both locations. Responses to fall versus spring applied sulfur were inconsistent and varied between locations. Initial results of this study suggest that where wheat yields are affected by tillage, higher rates of nitrogen and high rates of sulfur will not eliminate the effects of tillage.

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Nitrogen Uptake by Corn in a Winter Legume Conservation-Tillage System

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Introduction

The use of winter annual legumes in conservation-tillage systems can reduce soil erosion, improve soil productivity, increase infiltration of rainfall, conserve soil water, and furnish N to subsequent summer grain crops. Estimates of N contributed to subsequent crops generally range from 50 to 100 lb/acre (Hargrove, 1986; Neely et al., 1987; Tyler et al.. 1987; Ebelhar et al., 1984, Touchton et al., 1982).

Research with corn *(Zea mays* L.) grown in conventional-tillage systems has generally shown the benefit of delaying application of the majority of N fertilizer until 4 to 6 weeks after planting (June et al., 1972; Bigeriego et al., 1979; Welch et al.. 1971). Although delayed application of N has also been shown to increase N efficiency of corn in no-till systems (Fox et al., 1986; Frye et al., 1981), nitrogen dynamics in no-till legume systems complicate timing of fertilizer N applications. The delay in growth because of low soil temperatures associated with no-till systems in the Corn Belt is not appreciable in the South. Thus, demand for N by corn in no-till systems in the South occurs earlier in relation to planting date. This fact is exacerbated by the relatively slow release of N from winter legumes in conservation-tillage systems. Wilson and Hargrove (1986). using a mesh-bag technique. reported that 63% of N remained in crimson clover *(Trifolium incarnatum* L.) residue 4 weeks after plating bags in the field, as opposed to 40% remaining in bags under conventional tillage. Groffman et al. (1987), in a comparison of conventional and no-tillage systems, reported that tillage affected timing of N availability more than the total amount of available N. Huntington et al. (1985) reported that the majority of N mineralized from decomposing residues of hairy vetch *Vicia villosa* Roth) in a no-till system became available to corn after silking.

Synchronization of fixed-N release. fertilizer-N application time, and subsequent crop demand for N could improve N use efficiency of summer crops planted in winter legume conservation-tillage systems. This study was initiated to determine: 1) the N contribution from a winter annual legume to corn grown in a conservation-tillage system 2) the N uptake profile of corn grown in this type system, and 3) the optimum N rate and time of application for corn grown in this system on a coastal plain soil.

Materials and Methods

This field study was conducted for 3 years (1986-1988) on a Norfolk sandy loam (fine, loamy, siliceous, thermic Typic Paleudult) located in east-central Alabama. The soil is highly compactible, and the site has a well-developed tillage pan. The site was disked, field cultivated and seeded with crimson clover in mid-October of 1985, 1986, and 1987. At midbloom every year, clover was killed with gramoxone. A 'Brown-Harden Ro-Till' in row-subsoiler with unit planters was used to plant 'Pioneer 3320' corn in 30-inch rows 7-10 days after gramoxone application each year. Planting dates were 18 April, 5 May, and 29 April in 1986. 1987 ,and 1988, respectively. A starter fertilizer consisting of 120 lb/acre potassium-magnesium sulfate, 45 lb/acre triple superphosphate, 14 lb/acre zinc sulfate. and 8.75 lb/acre 'Solubor' was banded over the row. Plots were 4 rows wide and 35 ft long. Corn was thinned to 24.000 plants/acre 3 weeks after emergence.

The experimental design was a randomized complete block of 4 replications. Treatments consisted of a factorial arrangement of N fertilizer rates and application time. Nitrogen as ammonium nitrate, was broadcast at rates of 30.60, or 120 lb/acre. Zero-N checks were also included in both clover and rye *(Secale cereale* L.) check plots. Application times were at planting. or 3, 6 or 9 weeks later. In addition, split applications (1/3 at planting and the remainder 6 weeks later) of 60 and 120 lb N/acre were included. The test was not managed as irrigated corn, but if it did not rain within 2 days of N application, 3/4 inch of irrigation water was applied to move N into the soil.

Root and forage samples for dry matter and N determination were collected from clover and rye at time of gramoxone application. Corn whole plant samples were taken for dry weight and N concentration at 3 week intervals throughout the season until black layer. Stand counts were recorded periodically for calculation of N uptake. The middle 2 rows of each plot were harvested and weights were adjusted to 15.5% moisture for grain yield determination.

Results

Dry matter and N content of cover crops at burndown are listed in Table 1. Nitrogen content of clove and rye ranged from 99 to 156, and from 28 to 52 lb/acre, respectively. The percent of total N accumulated by cover crops found in screened root samples varied from 12.1 to 25.6% for clover, and from 9.7 to 15.6% in rye.

Table 1. Dry matter production and N content of cover corps at burndown, 7-10 days prior to planting corn.

	Dry Matter			N. Content		
Cover Crop	1986	1987	1988	1986	1987	1988
	lb/acre					
Clover	3904	5895	5479	99	156	123
Rye	2063	3906	2007	32	52	28

*USDA-ARS. National Soil Dynamics Laboratory. and Department of Agronomy and Soils. Alabama Agricultural Experiment Station, Auburn University. Alabama. respectively.

Corn Dry Matter Accumulation

In 1986, there was an extreme drought for the 12-week period following planting. Neither N rate nor timing of N application affected dry matter accumulation. The only treatment differences were between any treatment with supplemental N and 0-N checks in the rye and clover. Total dry matter accumulation at black layer averaged 14288 lb/acre for treatments with N fertilizer applied, 12055 lb/acre for 0-N plots in clover, and 7851 lb/acre for the rye check ($LSD_{0.10}$ = 1595 lb/acre).

In 1987, corn was planted late and rainfall distribution during the 5 week period centered around tasseling and silking was favorable. Both rate and time of N application significantly affected dry matter accumulation. Nitrogen rate had no effect on dry matter accumulation until later than 6 weeks after planting. By the end of the season, dry matter averaged 9329, 11374, 12967, and 14684 lb/acre for 0-N clover check, and 30.60, and 120 lb/acre N rates, respectively ($LSD_{0.10}$ = 1144 lb/acre). Rye check plots averaged only 3302 lb/acre dry matter 15 weeks after planting.

Applying N later than 3 weeks after planting generally reduced dry matter production in 1987. Dry matter produced 15 weeks after planting averaged 13671, 13573, 12320, and 12466 lb/acre ($LSD_{0.10}$ = 1320 lb/acre) for N applied at planting, or 3, 6, or 9 weeks later, respectively. Split applications were less effective for dry matter production than applying N at planting or 3 weeks later. In 1988, rainfall was generally favorable, with an excellent distribution during grain fill. As in 1986, there was no response to N rate nor application time, other than differences between 0-N checks and any treatment where N fertilizer was applied. Total dry matter accumulation at black layer averaged 14152 lb/acre for treatments with N fertilizer applied, 12257 lb/acre for 0-N plots in clover, and 3256 lb/acre for rye check plots ($LSD_{0.10}$ = 1504 lb/acre).

Nitrogen Uptake

In 1986, time of N application had no effect on N uptake. Nitrogen uptake by corn through the season followed similar patterns regardless of the time of application

In 1987 and 1988, N application timing produced significant differences in N uptake, however, differences were transitory and solely due to the treatment variable, i.e., withholding N fertilizer applications in relation to days from planting. For both years, by the end of the season, there was no difference in N uptake due to timing of N application. In 1988, however, there was a trend ($P<0.16$) for greater N uptake when fertilizer N was applied at planting. Total N uptake in 1988 averaged 219, 169, 159, and 167 lb/acre when N was applied at planting, or 3, 6 or 9 weeks later, respectively. Split applications did not result in greater N uptake in any year.

The I20 lb/acre N rate resulted in greater N uptake than the 30 or 60 lb/acre N rates in 1986 (Fig. 1). Nitrogen uptake in 0-N clover plots was 47 lb/acre greater than in rye plots. The apparent amount of fertilizer N recovered (N content from fertilized plots - N content from 0-N clover plots) was similar for the 30 and 60 lb/acre N rates, averaging 20 Ibiacre. For the 120 lb/acre N rate, the apparent fertilizer N recovered was 48 lb/acre. In 1987, the difference in N uptake patterns among N rates was evident 6 weeks after planting (Fig. I). By the end of the season, N uptake in 0-N clover plots was 60 lb/acre greater than in rye plots. Apparent N recovery of fertilizer averaged 94%, 97%, and 83% for the 30, 60, and 120 lb/acre N rates, respectively. Nitrogen uptake patterns in 1988 were generally similar to those in 1986. (Fig. I). The 120 lb/acre N rate resulted in greater N uptake 6 weeks after planting, however, by the end of the season there was little difference among total N uptake regardless of N rate. Total N uptake for the 30 and 60 lb/acre N rates were similar and averaged 39 Ibiacre more than that in 0-N clover plots. Corn fertilized with 120 lb/acre N took up 56 lb/acre more N than corn in 0-N clover plots.

Grain Yield

In 1986, time of N application did not affect grain yield (Table 2). However, at the 120 lb/acre N rate, split application resulted in the highest yields (133 bu/acre). Yields, at the 120 lb/acre N rate, were equivalent for N applied at planting, or 3, 6, or 9 weeks later (107 bu/acre averaged). In 1987 and 1988, delaying N application until 9 weeks after

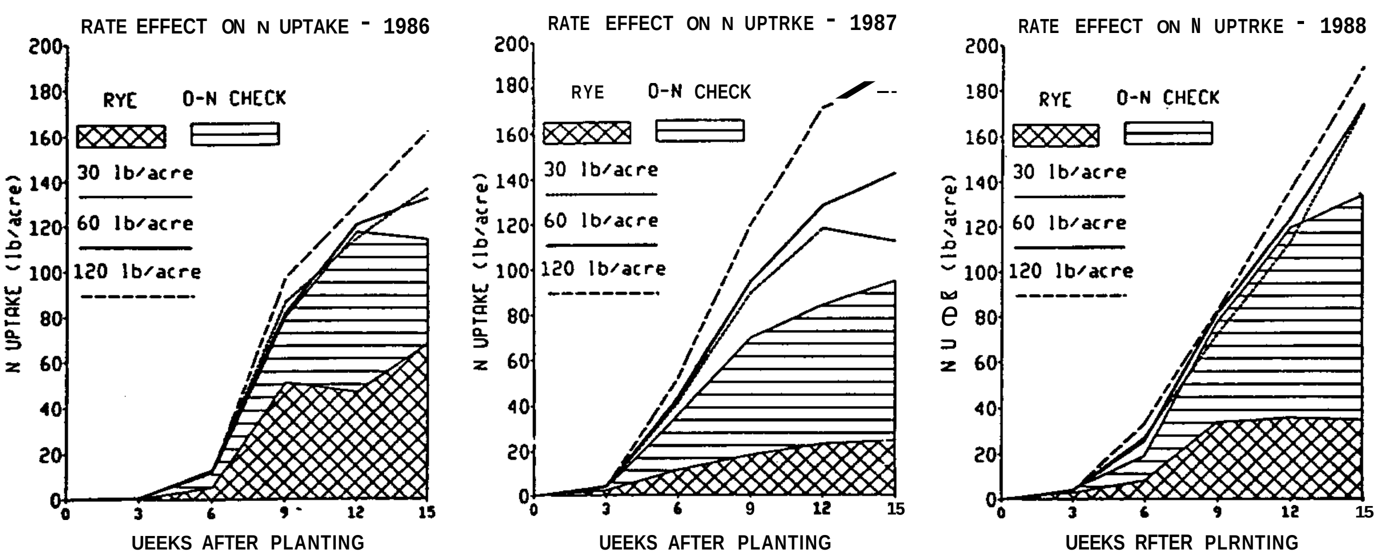

Figure 1. Nitrogen uptake of corn grown in a winter legume conservation-tillage system as affected by fertilizer N rate.

Table 2. Effect of N application time, averaged over N rate, on grain Yield of corn grown in a conservation-tillage system with crimson clover.

	N Application Time, wk after planting				
	0	3	6	9	$LSD_{0.10}$
	bu/acre				
1986	104	105	108	109	13.4
1987	107	112	106	81	7.6
1988	124	121	119	111	11.4

Table 3. Effect of N rate, averaged over application time, on grain yield of corn grown in a conservation-tillage system with crimson clover.

	N, lb/acre					
	0	30	60	120	Rye check	$LSD_{0.10}$
	bu/acre					
1986	77	92	92	107	2	11.7
1987	68	92	103	108	2	6.6
1988	106	116	123	117	22	9.8(NS)

planting decreased yield (Table 2). There was no benefit from split applications either of these years.

In 1986, maximum yield was obtained with 120 lb/acre N (Table 3). In 1987, a year of good rainfall distribution, optimum yield was obtained with only 60 lb/acre despite the fact that corn fertilized with 120 lb N/acre took up an additional 41 lb N/acre over that fertilized with 60 lb N/acre. In 1988, the greatest response to N rate came with the first 30 lb/acre applied (Table 3).

Conclusions

In 2 of 3 years, neither N rate nor application time affected total dry matter accumulation of corn grown in a winter legume conservation-tillage system. In I year, when corn was planted late and rainfall distribution was excellent, dry matter production was proportional to N rate, and applying N later than 3 weeks after planting reduced dry matter production. Application time did not affect total N uptake, but did effect grain yield. Applying N later than 6 weeks after planting reduced grain yield in 2 or 3 years. Delaying N application beyond 6 weeks had a negative effect on grain yield except in a year of extreme drought. Grain yield responded to 120, 60, and 30 lb N/acre, respectively, in successive years. Results from this study indicate that for nonirrigated corn grown in a winter legume conservation-tillage system on sandy coastal plain soils; the optimum management practice for conservation of N, energy, time and labor would be to apply 60 lb N/acre at planting.

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Predicting Nutrients From Winter Cover Crops For No-Till Management

Greg D. Hoyt[1]

Introduction

Farmers have used legume cover crops for many years as a green manure source for cultivated cropping systems. Farm managers have often placed legume cover crops in a crop rotation to produce a substantial quantity of biologically fixed N and to recycle other plant-essential nutrients—P, K, Ca, Mg—in the soil. The introduction of conservation tillage brought the ability to continue cover crop growth past the normal spring plowdown. This provides additional biomass and increases the quantity of N and other plant nutrients accrued into the cover crop.

Growth of legume cover crops depends upon geographic location and climatic conditions (1). Cropping sequence also plays a major role in biomass and nutrient accumulation. Growers who wish to plant summer crops (corn) early in the spring are limited to a few legume species that will provide substantial biomass and nutrients. Farmers producing grain sorghum, tobacco, or vegetables, such as tomatoes, squash, snapbeans, or sweetcorn, require wanner soil and air temperatures before planting or transplanting. This delayed planning enables them to choose from a wider selection of winter legumes that produce sufficient biomass and increase nutrient accruement by late spring.

Various legumes and grass cover crops have been planted in western North Carolina at elevations of 2000-3000 ft. from 1982 to 1987. I measured biomass and nutrient accumulation for these cover crops before use in a tobacco, corn. or vegetable system. Plant foliage was collected from May 1 to May 20 depending upon the desirable time of planting for the subsequent crop. Biomass means (Table 1) reflect various harvest dates of the cover crops and provide a comparison of the legumes listed with standard grass species (rye). Other legume and grass species were planted in these various tests, but those listed have been selected due to their productivity and use in this area of North Carolina.

Aboveground plant biomass measurements (Table 1) showed rye cover crops had the highest accumulation of organic matter (5,189 pounds/acre). Crimson clover and Austrian winter peas generally had excellent biomass for residue or plowdown and average 4,279 and 3.531 pounds/acre, respectively. Caley peas, hairy vetch and sub. clover had the lowest biomass measurements of these selected covers, but still provided ample residue for plow down. These measurements represent normal growing cycles of each species with rye producing sufficient ground cover in the fall, providing excellent soil coverage through the winter, and continued earlier growth in the spring. Crimson clover also provided some soil protection during the winter months. Peas and vetch generally provided less soil coverage.

Two important plant nutrients that are accrued and recycled efficiently by cover crops are N and K. Under many cropping systems high fertilizer inputs and low summer crop use results in N and K remaining in the soil and susceptible to fall leaching. Both legume and grass cover crops remove high quantities of N and K from the soil. Legumes accrue more K than grasses. Legumes also exceed grass cover crops in accumulation of N, with a large proportion of that N generally supplied by symbiotic N fixation. Hairy vetch and both peas provided the highest quantity of N in the aboveground portion of the plant. Crimson clover tended to have lower quantities of N in the plant, but still higher than the grass species. Calcium seemed to be readily taken up by the legumes, with well over twice as much Ca in legumes than rye. Less P and Mg accrued in the plant for both them legume and grass species, with little differences among species.

Table 1. Biomass yield and nutrient accrument by selected cover crops.

Cover Crop	Reps	Biomass	Nitrogen	Potassium	Calcium	Phosphorus	Magnesium
		lbs/acre					
Hairy Vetch	72	3171*	114	107	36	13	8
Crimson Clover	81	4279	101	111	56	11	10
A. Winter Peas	38	3531	119	110	34	13	10
Caley Peas	14	3176	115	101	33	12	9
Subterranean Clover	51	3291	86	93	46	10	9
Rye	66	5189	69	87	18	13	7

*Dry weight of above-ground plant material.

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Calculating Nutrients in Cover Crops

An ultimate goal of a grower using cover crops as a green manure is to predict the amount of nutrients in the cover, the percentage that will decompose that summer, and then reduce accordingly the soil test recommendation of fertilizer for the following summer crop. This prediction normally requires three measurements: the amount of biomass (dry weight), the elemental composition of the cover crop, and the decomposition rate of the cover crop during the summer for release of the nutrients. Biomass measurements are relatively easy and require little time or expense. Drying and weighing the cover crop requires only a microwave or normal oven and a small balance.

I measured plant moisture content of the four cover crops from one location (May 15 harvest). The moisture content of rye was 53%; crimson clover, 73%; Austrian winter peas, 84%; and hairy vetch, 85%. Plant water content should be higher in the spring and decrease with the age of the cover crop. Thus, measurements taken in early or late spring should not be generalized for calculations. Plant elemental composition requires more time and cost for analysis. Determining decomposition rate involves great expense and lots of

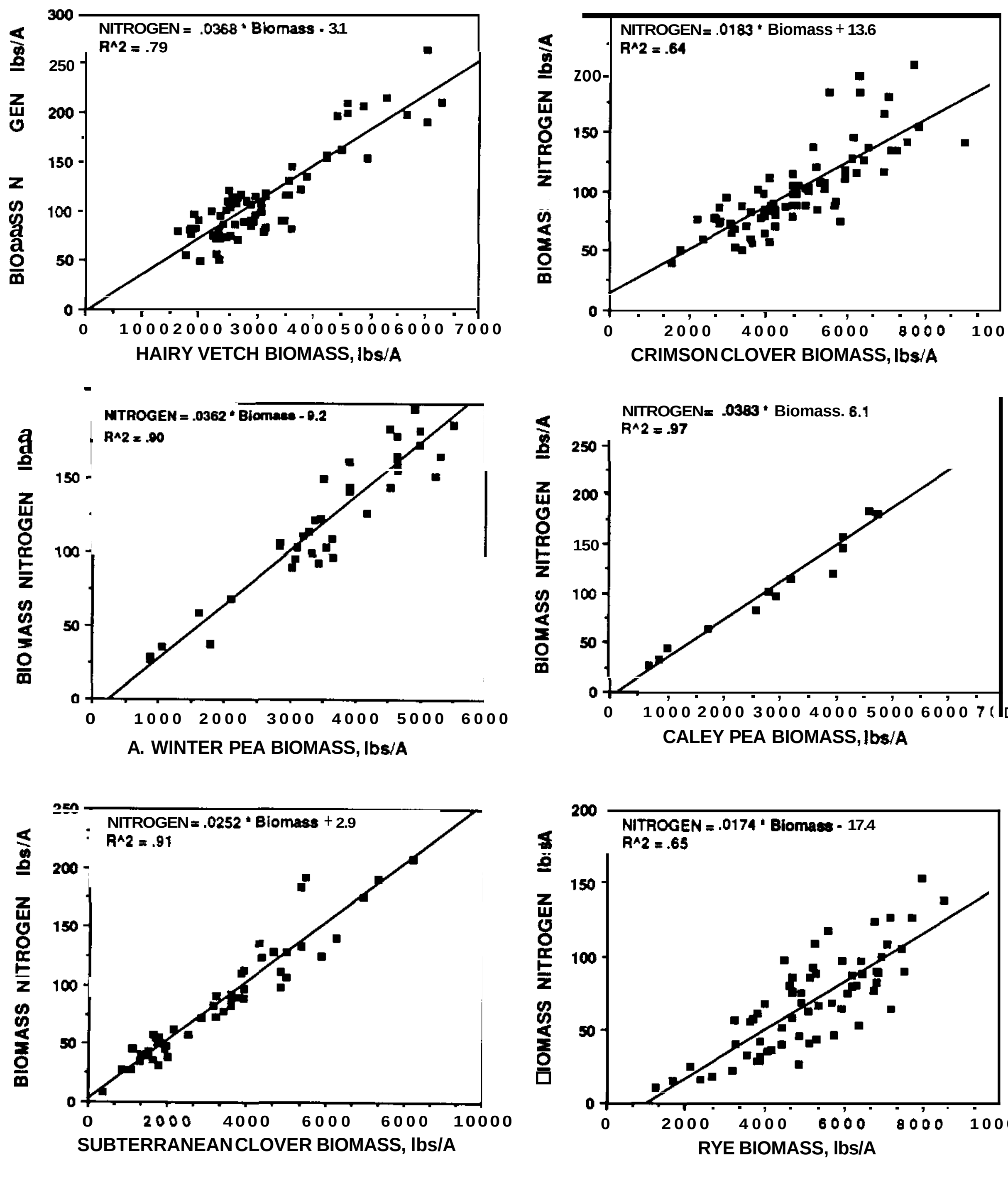

FIGURE 1. PLANT NITROGEN UPTAKE FOR SELECTED COVER CROPS

measurements, but has been measured by a few researchers.

Calculating plant nutrients available from a cover crop can be done as follows:

(a) Remove a square foot or yard of cover crop from the field, dry it and weight it or (b) weigh the fresh weight, take a subsample of the cover crop, dry the subsample, and use the following equations:

$$\text{Percent plant moisture content} = \frac{(\text{wet weight} + \text{hap weight}) - (\text{dry weight} + \text{hag weight})}{(\text{wet weight} - \text{hag weight})} \times 100$$

Remove the moisture content from the cover crop by:

Dry plant weight = (wet weight - bag weight) x [1 - (moisture content - 100)]

Calculate the biomassiacre by one of the following equations:

Square yard of cover crop

Dry weight in pounds x 4,800 = pounds dry biomass/acre

Square foot of cover crop

Dry weight in pounds x 43,560 = pounds dry biomass/acre

Once the weight of dry biomassiacre has been calculated, N and other nutrients can be calculated by using this value in one of the six equations in Figure 1 and the nutrient ratios in Table 2.

Table 2. Nutrient ratios of selected cover crops.

Cover Crop	Nutrient ratio				
	N	K	P	Ca	Mg
Hairy vetch	1 :	.97 :	.11 :	.34 :	.08
Crimson clover	1 :	1.13 :	.11 :	55:	.10
A. Winter Peas	1 :	1.00 :	.12 :	.30 :	.09
Caley Peas	1 :	.87 :	.10 :	.30 :	.08
Subterranean clover	1 :	1.05 :	.12 :	.55:	.11
Rye	1 :	1.34 :	.20 :	.26 :	.11

For example, for hairy vetch (from Figure 1):

N content = ,0368 x plant biomass (poundsiacre) - 3.1

Using a realistic value of 3.000 pounds of vetch cover/acre. the results would be as follows:

Ncontent = (.0368 x 3,000) - 3.1 = 107.3 pounds N/acre

Continuing with Table 2 then calculates the quantity of K, P, Ca, or Mg in a vetch cover crop:

107.3 pounds N x .97 = K content = 104.1 pounds/acre K

107.3 pounds N x .11 = Pcontent = 11.8 pounds/acre P

107.3 pounds N x .34 = Cacontent = 36.5 pounds/acre Ca

107.3 pounds N x .08 = Mg content = 8.6 pounds/acre Mg

These values represent the total nutrients in the cover crop at desication. The rate of decomposition during the summer row crop growing season will determine the quantity released and available.

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Tillage Systems for Summer Crops Following Winter Grazing

J.T. Touchton, D.W. Reeves, and D.P. Delaney[1]

Introduction

Wisely managed conservation-tillage systems arc low-input production systems that help maintain soil productivity and reduce environmental pollution by decreasing soil erosion and water runoff. During the past decade. research efforts have been directed towards matching the most economical conservation-tillage system with specific soils and crops. The different tillage requirements among crops and soils are related to the compactability of the soil and sensitivity of the crop to compacted soils.

Although research has been conducted to determine tillage needs for specific crops in mulitple-cropping systems and rotations. this research has not been designed to identify tillage needs for summer crops following winter grazing. Throughout the Southeast, winter grazing is an integral part of most diversified farming systems. In Alabama alone, over 400,000 acres of summer row-crop land are grazed during the winter months. Since the compaction potential due to winter grazing is high, and since the need or lack of a need for tillage is highly correlated with compaction, this research is being conducted to determine the effects of animal traffic on compaction and tillage needs for summer crops following winter grazing.

Materials and Methods

The information presented in this paper is from the first year of a 3-year test. This study is being conducted at Auburn University's Sand Mountain Substation in northeast Alaba-

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ma. The soil is a Hartsel sandy loam, which is typical of soils located along the Appalachian Plateau in northern Alabama. Although compaction problems have been identified in these soils, the problems are generally not as severe as those which exist in the sandy Coastal Plain soils of south Alabama.

Treatments consist of grazed and nongrazed rye during the winter months, and tillage prior to planting the summer crop. Summer crop tillage treatments are: 1) no tillage, 2) no tillage with in-row subsoiling at planting, 3) disk only, 4) chisel plow-disk, 5) paraplow, and 6) moldboard plow - disk. Cows were taken off the winter grazed plots 3 weeks prior to the target planting date for corn, and the grazed and nongrazed rye was killed with Roundup. All preplant tillage operations were one week after the rye was killed. The corn, 'Pioneer 3165', was planted in 30-inch row widths on 8 April 1988, which was 3 weeks after the rye was killed. Recommended production practices were followed for fertilizer and pesticide use .

One month after planting, soil compaction-related data were collected. These date included penetrometer readings at 2.8-inch increments down to the 20-inch depth, both in the row and in the tire-track middles; soil moisture at 5-inch increments down to 20-inch depth; and bulk density in the upper 4 inches of soil. Ear leaf samples were taken during midsilk so that nutrient uptake could be evaluated. Grain yields were taken at maturity. The spring and summer period of 1988 was exceptionally dry and not a typical growing season. The corn was not imgated. As with any data collected during the single growing season, extreme care should be exercised when these date are used to make major management decisions.

Results

As a result of the extremely dry growing season, corn grain yields (Table 1) were 30 to 40 bu/acre lower that normally expected for the Sand Mountain region. There was, however, a strong relationship between yield and treatments. When averaged across all tillage treatments, winter grazing resulted in a 14 bu/acre yield reduction. Without grazing, no tillage and no tillage with in-row subsoiling resulted in the highest yields, 82 and 87 bu/acre, respectively. Yields with the other treatments ranged between 69 and 73 bu/acre. Lower yield with than without tillage is not uncommon in the

Table 1. Tillage effects on yield of corn following grazed and nongrazed rye.

Rye grazed	Tillage for corn					
	No-till	No-till*	Disk	Chisel	Turn	Paraplow
	bu/acre					
Yes	57	65	46	60	66	77
No	82	87	69	72	71	73

* Indicates no tillage with in-row subsoiling.

Sand Mountain region. When corn followed grazed rye, there was definitely a need for deep tillage. Highest yields obtained with deep tillage occurred with the paraplow, but even these yields were 10 bu/acre lower than those obtained with the highest yielding treatment when corn followed nongrazed rye. Although yields obtained with deep tillage in the grazed area were less than the highest yields in the nongrazed area, yields with both the paraplow and moldboard plow were approximately equal for the grazed and nongrazed area.

Soil compaction data (Table 2) taken 4 weeks after planting (7 weeks after removing cattle) suggest that the effect of animal traffic on compaction is not limited to the surface few inches of soil. Compaction effects were measurable at the 20-inch depth. The values listed in table 2 are in bars, which is a measure of resistance, and the higher the number the more compact the soil. Disking appeared to eliminate compaction caused by grazing down to the 2.8-inch depth, but in the nongrazed plots, it appeared to have created a disk pan between the 5.5- and 8.3-inch depths. All of the deep tillage implements appeared to have eliminated the compaction caused by grazing down to depth of tillage, which was approximately 8, 11, 11, and 17 inches for the chisel plow, in-row subsoiler, moldboard plow, and paraplow, respectively. The paraplow was most effective in loosening the soil, and it was the only deep tillage implement that appeared to have tilled as deep as the animal traffic compacted the soil.

Interrow traffic from planting and postplant cultivation can also cause compaction problems, which can adversely effect yields by restricting root growth into the row middles. Date in Table 3 show the effects of planting traffic on soil compaction. Compaction cause by planting traffic appeared to be an additive effect to grazing. Within the strict no-tillage plots, additional compaction occurred only in the upper 2.8 inches of soil, and difference between the grazed and nongrazed plots was the same (4 to 5 bars) as within the row (Table 2). Within all tillage plots, the planting traffic essentially eliminated the beneficial effects of tillage, and compaction depth was identifiable at the 16-inch depth. It appears that soils tilled with the chisel plow are least susceptible to recompaction in the surface few inches of soil, but those tilled with the paraplow are least susceptible to recompaction at depths of 11 to 16 inches.

When compared to no grazing, winter grazing resulted in lower concentrations of P, K, Ca, and Mg in the earleaf during midsilk (Table 4). Tillage, however, did not improve leaf nutrient concentrations in the grazed plots. In the nongrazed area, deep tillage greatly increased the K concentration in the ear leaf. There is no explanation for the tillage effect on leaf K when corn followed nongrazed rye but not grazed rye.

Table 2. Soil cornpaction in the row as affected by animal traffic and tillage after grazing.

Soil depth	Tillage after grazing											
	No-till		Disk		No-till$		Chisel		Para-plow		Moldboard plow	
	Yes†	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
inches	soil resistance, bars§											
2.8	20	16	4	9	5	5	5	7	**8**	10	5	6
5.5	25	24	24	25	2	3	14	16	11	11	11	10
8.3	24	20	22	22	8	4	15	17	9	7	14	10
11.0	19	15	19	15	17	12	20	17	**8**	6	18	12
13.8	16	14	17	14	19	12	18	12	7	6	16	12
16.5	18	15	18	16	21	12	21	14	9	9	18	18
19.6	20	17	20	20	24	13	24	19	18	17	20	22

†Yes indicates that plots were winter grazed and No indicates no winter grazing.
‡Indicatcs no tillage with in-row subsoiling
§the highcr the numbcr the more compact the soil. 25 bar is the measurable maximum.

Table 3. Soil compaction in the row middles (tire tracks created at planting) as affected by animal traffic and tillage after grazing.

Soil depth	Tillage after grazing											
	No-till		Disk		No-till$		Chisel		Para-plow		Moldboard plow	
	Yes†	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
inches	soil resistance, bars$											
2.8	25	20	20	20	21	19	16	15	18	18	18	17
5.5	25	22	25	24	23	24	21	19	14	18	17	15
8.3	24	18	25	22	23	19	22	19	22	12	20	13
11.0	24	15	25	18	21	14	22	16	9	9	19	16
13.8	18	16	17	16	20	25	17	25	10	10	19	15
16.5	21	19	18	18	25	14	21	15	13	14	20	21
19.6	23	21	23	23	25	16	25	20	21	20	22	25

†Yes indicatcs that plots were winter grazed and No indicates no winter grazing.
‡Indicatcs no tillage with in-row subsoiling
§the higher the numbcr the more compact the soil. 25 bar is the measurable maximum.

Table 4. Nutrient concentration in corn ear leaf during mid silk as affected by winter grazing and tillage prior to planting corn.

Tillage	Winter grazed	N	P	K	Ca	Mg	Mn	Zn	B
		Nutrients in the ear leaf							
		%					ppm		
No-till	Yes	2.30	.19	1.13	.36	.14	66	31	30
	No	2.32	.23	1.34	.51	.23	52	28	30
Disk	Yes	2.09	.18	1.33	.31	.14	43	31	34
	No	2.12	.22	1.37	.51	.23	38	28	33
No-till‡	Yes	2.30	.19	1.24	.41	.16	26	27	25
	No	2.29	.22	1.36	.51	.21	52	26	35
Chisel	Yes	2.08	.18	1.19	.38	.16	37	24	28
	No	2.15	3 2	1.50	.47	.21	32	25	51
Paraplow	Yes	2.04	.17	1.14	.43	.16	44	34	29
	No	2.12	.21	1.50	.46	.20	57	31	28
Turn	Yes	2.04	.18	1.20	.42	.17	38	21	28
	No	2.07	.24	1.60	.46	.22	30	24	23
Average	Yes	2.14	.18	1.20	.39	.16	42	28	29
	No	2.18	.22	1.44	.49	.21	44	32	34

‡No-till* is no tillage with in-row subsoiling.

Summary

The results from this one year of data suggest that compaction created by animal traffic during winter grazing is not restricted to the surface few inches of soil. In addition, it appears that compaction created by animal grazing may be as much as 10 inches deeper than compaction created by tractor tires during planting. Yield of corn following grazed and nongrazed rye suggests that grazing can have a severe adverse effect on grain yield. Deep tillage following grazing can partially but not completely eliminate this adverse effect. It also appears that deep penetrating tillage implements, such as the paraplow, are much more effective in eliminating this adverse effect than an in-row subsoiler or a chisel plow. There were also indications that grazing or the compaction created by grazing interfered with uptake of P, K, Ca, and Mg but not N, Cu, Mn, Zn, and B. These studies will have to be continued for several years to determine if there is a strong relationship between climatic conditions and winter grazing on yield of the following summer crops.

Microbiological Characterization of Eroded Soils in Conservation Tillage Systems in the Georgia Piedmont

D. Jordan, R. R. Bruce and G. W. Langdale[1]

Introduction

Soil microorganisms play an important role in the retention and release of nutrients and energy. Any attempts to assess nutrient and energy flow in the soil system must take the soil microbial biomass into account (Parkinson and Paul, 1982). In agricultural soils, the microbial biomass acts as a source-sink for labile nutrients. Cropping practices which alter the size of the microbial biomass or its rate of turnover can affect crop growth (Granatstein et al., 1987). Microbial biomass responds more quickly to management changes than does organic C or N (Nannipieri, 1984) and has an important role in residue decomposition (Adams and Laughlin, 1981). In conservation tillage systems where plant biomass inputs are diverse with varying C to N ratios, understanding how these materials are decomposed and recycled by the biological community is necessary to assess nutrient availability to subsequent crops. The decomposition process is influenced by a variety of environmental, climatic and soil conditions. The Georgia Piedmont soils are historically recognized as some of the most eroded areas of the United States and significant areas of shallow, clayey, surface soil layers are common (Bruce et al. 1987; White, 1985). These finer textured surfaces can absorb, retain and slowly release nut-

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rients. Our objective was to characterize microbial and chemical changes on the range of soil textures associated with different conservation treatments over the growing season.

Materials and Methods

We measured the microbial. chemical and physical changes associated with conservation tillage procedures (no-tillage and paratillage) during the 1988 growing season. Measurements were intended to characterize the range of conditions that are encountered in a representative portion of the landscape near Watkinsville. GA. In this preliminary report, we will focus on the microbial and chemical changes associated with conservation tillage practices.

General Soil Characteristics

A Cecil/Pacolet (clayey, kaolinitic, thermic Typic Hapludult) sandy loam and sandy clay loam was measured for chemical and biological changes across the landscape. The total N content for sandy loam and sandy clay loam was 0.05% and 0.1 I%, respectively. The pH was 6.0 for 0-10 cm across the landscape

Previous and Present Cropping Practices

The field had been previously no-till planted to soybeans for three years following long-term cropping using conventional tillage methods. One year prior to beginning the present experiment. the field had been left fallow with no-tillage and contained diverse weeds.

Prior to beginning this study in the fall of 1987. the whole experimental area was limed at two tons/acre of dolomite. Fertilizer was added at 50, 215, and 150 lbs of N, P_20_5 and K_20, respectively. The experimental layout included three winter cover crops (including a fallow treatment) and three conservation tillage treatments replicated five times in 500-ft long strips. Stacy wheat and Tibbe crimson clover were no-till planted as winter cover crops at a rate of I .5 bushels/acre and 25 lbs seed/acre. respectively. Ammonium nitrate was applied in February and July 1988 at a rate of 50 lbs N/acre to all wheat transects.

After the winter cover crops were killed with paraquat. grain sorghum (Sorghum bicolor L. Moench) was no-till planted across the entire field.

Preparation of Plant and Soil Samples for Analyses

The amount of plant biomass produced was determined by taking a fresh weight sample of each cover crop every 25 ft before complete kill. Subsamples were taken. washed. dried at 65°C for *2* days, weighed. then ground in a Wiley Mill 2 mm sieve screen and stored for further analyses.

Immediately after harvesting, each plant part was dried at 65°C for 2 days, weighed, then ground in a Wiley Mill 2 mm sieve screened for chemical analyses.

Soil samples were air-dried and subsampled for sieving on a 2 mm sieve.

Analytical Procedures

Total N analysis was determined on soil and plant samples by salicylate method using a flow-injector analyzer (Lachat) after a standard Kjeldahl digestion (Bremner, 1965).

Microbiological Procedures

Microbial biomass C was determined by measuring the CO_2-C evolved from a chloroform fumigated sample minus a unfumigated sample after a 10-day incubation period in a mason jar kept at a constant temp (Parkinson and Paul, 1982). The mason jar contained a base trap (2N NaOH) which was removed at the end of the 10-day incubation and titrated with 0.I N HCI .

The number of bacteria produced at different depths across the landscape under varying soil textures and erosion levels were determined using a spiroplater and laser counter.

Results and Discussion

Clay content influenced the total nitrogen and C/N ratio of plant biomass inputs. A higher total nitrogen wasobserved in the lower clay content with an inverse relationship seen in the C/N ratio (Table 1). The total carbon remained constant across varying clay content (Table 1).

Table 1. Description of Crop Biomass Inputs and Erosion in Relation to Clay Content of Surface Soil and Percentage Total N, Total C, and CIN in Dawson Field in 1988.

Crop Inputs & Erosion	Range Clay Content (%)	Quant. of Biomass Added $g^{-1}ft^2$	Percentages Total C	Total N	C/N*
Wheat					
high clay (severe)	14-41	86	40.5	0.73	*56*
low clay (slight)	4-7	155	40.5	0.99	41
Clover					
high clay (severe)	14-41	49	*39.9*	I.85	22
low clay (slight)	4-7	50	40.6	2.00	20

*Total Carbon/Total Nitrogen = C/N

Microbial biomass measures the quantity of energy stored in a particular segment of the biological community. In general terms, it means "mass of living material" (Atlas and Bartha, 1987). In May, a high microbial activity was observed as freshly killed residues began to decompose and continued through June with slightly less activity probably due to less freshly decomposed material and onset of dry weather conditions. This is readily seen in July when severe drought occurred last summer and the residues had become more lignified, thus causing a slower decomposition rate (Table 2). Near the end of the growing season when weather conditions become more favorable (eg. more rain). the microbial activity increased.

Interestingly, we observed more microbial activity in the high clay sites than low clay sites in May. but slightly less than the low clay sites throughout the growing season. This suggests that microbial population may be somehow bound or protected in the high clay sites. Further studies will be done to confirm this hypothesis.

Generally, the number of bacteria decreased with depth as expected (Table 3) . However, the overall population seemed

Table 2. Microbial Biomass Changes Associated with Varying Clay Content in Dawson Field in 1988 over the Growing Season.

Clay & Erosion		---------- $ugCO_2$-C evolved g^{-1} soil ----------			
		May	June	July	Oct.
			(0-2 in.)		
	range *(%)*				
High (severe)	14-41	740	487	263	520
Low (slight)	4-7	644	551	334	652

Table 3. Bacterial enumerations at various depths associated with clay content in Dawson Field in 1989.

Clay & Erosion		No. of [1]cfu $ml^{-1}g^{-1}$soil (10^7)		
		0-0.8	0.8-1.6	1.6-2.4
			(depth in.)	
	range (%)			
High clay (severe)	14-41	2.31	2.03	--
Low clay (slight)	4-7	2.56	1.21	I.06

[1]cfu = colony-forming units of bacteria
-- = data incomplete

relatively low (10^7) which is consistent with low microbial biomass seen in a degraded site (Table 3). With a long-term practice of conservation tillage and winter cover crops, we expect that microbial number and activity will increase over time.

In the Georgia Piedmont, this microbial biomass carbon varies according to locale and cropping history, but has the same general trend of decreasing numbers for depth within the soil profile (Table 4). Most of the microbial activity will be observed in the surface soil where carbonaceous materials and nutrients (Rhizosphere effect) are present to stimulate greater microbial activity. Watkinsville site tends to have a lower biomass than Griffin or Horseshoe Bend because of degradation associated with erosion and continuous conventional tillage for many years (Table 4). The opposite effect is observed for Horseshoe Bend and Griffin where the soils have been in an aggradation phase for several years. The Griffin site has been in permanent sod for several years and the Horseshoe Bend site has had both conventional and no tillage treatments for 11 years.

Table 4. Microbial Biomass Carbon at Three Different Depths and Sites in the Georgia Piedmont.

Site	--------- ug CO_2-C evolved g^{-1} soil ---------		
	0-2	2-4	4-6
		(depth-in.)	
Watkinsville	418	236	I85
Horseshoe Bend (Athens)	763	214	212
Griffin	1110	529	423

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Soil Organic Matter in Long-Term Tillage and Cropping System Studies

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Abstract

Some reports advocate that no-tillage (NT) management builds up soil organic matter (SOM) compared with conventional tillage, (CT) while others disagree for some environments. The purpose of this study was to determine the influence of cropping history and soil type on changes in SOM as affected by long-term NT and CT treatments. Three soil types and six cropping systems from seven experiments in Florida and Argentina were included in this study. Soils samples were collected in 2 in. increments from the 0 to 6 in. depth and in a 6 in. increment from the 6 to 12 in. depth in all seven experiments. In every treatment of all experiments SOM decreased progressively with increasing soil depth. No-tillage was higher in SOM near the soil surface compared to CT. Amounts of SOM between tillage was greater for NT in four or seven cropping systems studies when averaged over the 0 to 12 in. depth suggesting that NT may build up SOM in most cases compared to CT. Build up of SOM in the soil surface layer is offset by a proportionate loss in the lower depths within the 0 to 12 in. sampled area for some cropping systems.

Introduction

Minimum tillage and double-cropping systems are being adopted rapidly by the agricultural community in the U.S. and other countries. Minimum tillage is described as "Planting directly into an unprepared seed-bed and the elimination of tillage operations through harvest, whereas, multiple-cropping is growing two or more crops in the same year on the same land area" (Gallaher, 1979a).

The increasing use of minimum-tillage and double-cropping in the southeastern U.S. requires a better understanding of their effect on soil organic matter (SOM) content (Gallaher, 1979b). Several authors (Corella, 1989; Gallaher, 1979b; Gallaher and Ferrer, 1987; Gallaher. et al., 1987: Ortiz and Gallaher, 1984) report that the amount and distribution of SOM from decay of residues will be altered after several years in a reduced-tillage system. Two Indiana studies (Cruz. 1982; Fernandcx, 1976) on soils differing widely in natural SOM content. showed that SOM increased near the soil surface (0 to 4 in.) with reduced tillage, and was maintained or increased slightly below the 4 in. soil depth with no-tillage (NT) treatments compared with conventional tillage (CT) treatments at the 0 to 2 in. depth in a 6 yr-old experiment. Ortiz and Gallaher (1984) found that NT treatments had I I%' more SOM than CT treatments in the 0 to 2 in. depth. Accumulation of SOM in the top 4 in. was reported by Gallaher, (1979b); and Gallaher and Ferrer (1987).

In Ohio (Dick, 1983) the increase in SOM for NT over CT was 2.5 times on a dark silty clay loam and 2.2 times on a light-colored slit loam. Below the 3 in. soil depth, SOM was about equal for the two systems on the light soil, but was reduced for NT on the dark soil, possibly through restricted rooting. Research in Kentucky (Blevins et al., 1977) showed that the SOM level in the top 2 in. of soil under an original bluegrass (*Poa pratensis* L.) sod was reduced only slightly after *5* yr of continuous corn *(Zea mays* L.) when NT, cover crops, and high fertility levels were used. Moldboard plowing reduced SOM by 4.6% in the 0 to *2* in. layer. Different cropping systems affected the C and N status of soil in a short time period (Sprague and Triplett, 1986). In general, systems returning small amounts of residue resulted in larger losses of C and N than systems returning large amounts of residue.

The purpose of this study was to determine the influence of cropping history and soil type on changes in SOM as affected by long-term NT and CT treatments.

Materials and Methods

Three soil types and six cropping systems from seven long-term experiments in Florida and Argentina were included in this study. The three experimentss from Argentina were under investigation by INTA (Instituto Nacional de Techologia Agricola) at Marcos Juarez, Cordoba. The four experiments from Florida were under investigation by the Inst. of Food and Agr. Sci., Gainesville, and Williston, FL. Experiments from Argentina were from a Typic Agriudoll soil and included: 1) an I I yr-old monocrop corn *(Zea mays* L.) study, 2) a 10 yr-old monocrop soybean *(Glycine max* L. Merr) study, and 3) a 6 yr-old wheat *(Triticum aestivum* L.)/soybean double cropping study. Three of the four Florida experiments were conducted on Grossarenic Paleudults near Gainesville and included: I) a 10 yr-old rye *(Secale cereale* L.)/summer crop (grain sorghum, *Sorghum bicolor* L. Moench) the first 4 yr or corn the last 6 yr) study. 2) an I1 yr-old oatigrain sorghum study, and *3)* an I I yr-old oat/soybean study. The fourth Florida experiment was on a Typic Haplustalf, located at Williston, and was a 6 yr-old monocrop corn study.

All seven experiments had randomized complete block designs and had the same NT and CT variables in common. In all cases the soil samples were taken in the fall of the year at the end of the growth of the summer crop and just prior to plowing CT plots. In each experiment soil samples were taken in 2 in. increments from the 0 to 6 in. depth and in a 6 in. increment from the 6 to 12 in. depth. Samples were air dried, ground, and sieved to pass a 2 mm stainless steel screen. The Potassium Dichromate procedure (Walkley. 1947; Allison, 1965) was used to determine SOM on three replications from each experiment. The statistical analysis was done using MSTAT (1987 version 4.0).

Results and Discussion

In all seven experiments SOM decreased with soil depth for both tillage treatments, hut the decrease was more pronounced in NT (Tables 1 and 2). No-tillage was higher in

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Table 1. Effect of tillage, soil depth, cropping system and soil type on soil organic-matter.

Cropping System	Loc.	S. Type	Depth	NT	CT		Difference
			-- in.	----	---- %	----	----
Corn monocrop	ARC	Mollisol	0 - 2	3.27a	2.94a	*	+0.33
			2 - 4	2.88 b	2.85a	NS	+0.03
			4 - 6	2.57 c	2.45 b	NS	+0.12
Corn monocrop	FLA	Alfisol	0 - 2	1.99a	1.59a	*	+0.40
			2 - 4	1.64 h	1.33 b	*	+0.31
			4 - 6	1.49 c	1.19 c	*	-0.30
Rye-summer crop	FLA	Ultisol	0 - 2	2.05a	1.62a	*	+0.43
			2 - 4	1.41 b	1.32 b	*	+0.09
			4 - 6	1.14 c	1.32 b	*	-0.18
Wheat-soybean	ARC	Mollisol	0 - 2	3.44a	2.89a	*	+0.55
			2 - 4	2.68 b	2.80a	*	-0.12
			4 - 6	2.43 c	2.70 h	*	-0.27
Soybean monocrop	ARG	Mollisol	0 - 2	3.36a	2.94a	*	+0.42
			2 - 4	2.72 b	2.73 b	NS	-0.01
			4 - 6	2.36 c	2.53 c	*	-0.17
Oat-soybean	FLA	Ultisol	0 - 2	2.55a	2.05a	*	+0.50
			2 - 4	1.51 b	1.69 b	*	-0.18
			4 - 6	1.16 c	1.49 c	*	-0.33
Oat-sorghum	ARG	Ultisol	2 - 4	1.57 b	1.59 b	NS	-0 02
			4 - 6	1.20 c	1.44 c	*	-0.24

Data in columns within a cropping system followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan multiple range test. Data in rows with NS = non significant and * = significantly different at the 0.05 level of probability. ARG = Argentina, FLA = Florida, NT = no-tillage, CT = conventional tillage.

Table 2. Effect of tillage, soil depth, cropping system and soil type on soil organic matter.

Cropping System	Location	Soil	NT	CT		Difference
			- % in 0 - 6 in. depth --			
Corn monocrop	Argentina	Mollisol	2.91	2.75	*	+0.16
Corn monocrop	Florida	Alfisol	1.71	1.37	*	+0.34
Sye-summer crop	Florida	Ultisol	1.53	1.43	*	+0.10
Wheat-soybean	Argentina	Mollisol	2.85	2.80	NS	+0.05
Soybean monocrop	Argentina	Mollisol	2.81	2.73	NS	+0.08
Oat-soybean	Florida	Ultisol	1.74	1.74	NS	0.00
Oat-sorghum	Florida	Ultisol	1.77	1.61	*	+0.16
			- % in 6 - 12 in. depth -			
Corn monocrop	Argentina	Mollisol	1.73	1.63	NS	+0.10
Corn monocrop	Florida	Alfisol	0.94	1.08	*	-0.14
Rye-summer crop	Florida	Ultisol	0.88	0.74	*	+0 14
Wheat-soybean	Argentina	Mollisol	1.68	1.41	*	+0.27
Soyhean monocrop	Argentina	Mollisol	1.67	1.12	*	+0.55
Oat-soybean	Florida	Ultisol	1.05	0.98	NS	+0.07
Oat-sorghum	Florida	Ultisol	0.91	1.02	NS	-0.11
			- % in 0 - 12 in. depth -			
Corn monocrop	Argentina	Mollisol	2 32	2.19	NS	+0.13
Corn monocrop	Florida	Alfisol	1.33	1.?3	*	+0.10
Rye-summer crop	Florida	Ultisol	1.21	1.09	*	+0.12
Wheat-soybean	Argentina	Mollisol	2.27	2 11	*	+0.16
Soybean monocrop	Argentina	Mollisol	2.24	1.93	*	+0.31
Oat-soybean	Florida	Ultisol	1.40	1.36	NS	+0.04
Oat-sorghum	Florida	Ultisol	1.34	1.32	NS	+0.02

Date in rows followed by NS = Non significance and * = significantly different according to F test (P=0.05). NT = No-tillage, CT = Conventional tillage.

SOM in the top 2 in. compared to CT for all seven experiments. Several researchers found that NT had higher SOM at the soil surface as compared to CT systems (Blevins, 1977; Dick, 1983; Gallaher, 1979b; Gallaher and Ortiz, 1984, Gallaher, et al., 1987; Gallaher and Ferrer, 1987, Sprague and Triplett, 1986). In contrast, the data from this study does not agree with studies by Hargrove et al. (1982) who reported no increase in SOM after 5 yr of NT management. The increase in the top 2 in. for NT was at the expense of SOM losses in the 6 to 12 in. depth for both monocrop corn systems and losses in the 2 to 6 in. depth for all other systems.

Average values in the 0 to 6 in. depth showed that four of the seven experiments had accumulated more SOM in NT plots (Table 2). All four of these experiments had a summer fibrous root system of either corn or grain sorghum in common. The three systems that showed no change in SOM due to tillage treatment in the 0 to 6 in. depth had the tap rooted soybean summer crop in common.

Although there were exceptions, experiments with a tap root crop in the system tended to build up SOM in NT vs CT at the 6 to 12 in. depth while either a loss or no change occurred at this depth for systems containing fibrous root summer crops. Bruniard (1988) showed that tillage management changed the root pattern distribution in the soil profile. The root density of soybean in and oat-soybean double cropping system was higher in the 0 to 2 in. depth in NT plots and was highly correlated with SOM content.

At the top 12 in. four of the seven experiments accumulated greater amounts of SOM for NT compared to CT (Table 2). This included an experiment on a Florida Alfisol and a Ultisol and two experiments on a Argentina Mollisol. Systems showing the least change in SOM at the 0 to 12 in. depth were oat-soybean and oat-sorghum. These experiments are known to have tillage or hard pan formation which would restrict roots from deep soil penetration and may partially explain their deviate behavior (Vazquez, el al., 1989).

Mollisols had about 70% more SOM than the Alfisol and Ultisols in the 0 to 12 in. depth. The order of cropping systems ranked from highest to lowest in SOM at the 0 to 12 in. depth ws corn monocrop. Argentina > wheat-soybean, Argentina > Soybean monocrop, Argentina > oat-soybean, Florida > oat-sorghum, Florida > corn monocrop. Florida > rye-summer crop, Florida. In the Argentina experiments the ranking no doubt reflects the same or expected order of the quantity of residue returned to the soil. This principle does not appear to hold true in the Florida experiments.

Irrespective of soil type it is evident that the type of root system strongly influenced the build up or lack of build up of

SOM at any specific depth of soil by NT. These date indicate that cropping systems having fibrous root summer crops tend to build up SOM near the soil surface at the expense of losses at lower depths within the 0 to 12 in. depth. On the other hand, the lack of SOM build up by NT at the 0 to 6 in. soil depth appears to be at the expense of build up of SOM by NT at the 6 to 12 inc. depth for systems which have a tap rooted summer crop.

Conclusions

No-tillage accumulated more SOM in the 0 to *2* in. soil depth for all seven experiments irrespective of soil type or cropping system. Cropping systems which had fibrous root summer crops in the system accumulated SOM in the 0 to 12 in. soil depth at the expense of losses in SOM from the 6 to 12 in. soil depth. Cropping systems which had tap root summer crops in the system seemed to accumulate SOM in the 0 to 2 in. depth at the expense of SOM losses in the 2 to 4 in. depth. No-tillage accumulated greater quantities of SOM compared to CT in four of the seven long-term tillage studies that were investigated when averaged over the 0 to 12 in. soil depth.

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Slit-Tillage for Plow Pan Soils

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Introduction

Soil compaction in the form of plow pans, sometimes called tillage pans, is a problem on large areas of land throughout the world (DeRoo 1961, Eriksson et al., 1974. Unger et al., 1981). Plow pans are frequently a deterrent to optimum crop performance on the coarse textured soils of the Southeastern United States. The primary way in which plow pans adversely affect crop production is by reducing plant rooting into the subsoil. Often a plow pan will restrict most of a crop's roots to the plow layer. Oxygen deficiency and soil strength are the primary factors that restrict root growth in compacted soil (Barley et al.. 1967, Huck 1970, Eavis and Payne 1968, Greenwood 1969). Subsoiling is the most common management practice for promoting deep rooting on plow pan soils, however it has the disadvantages of: high power requirements; the slowing of tillage and planting operations; undesirable mixing of soil horizons; and short term benefits.

In 1979 research was begun to develop an alternative to subsoiling that would effectively promote rooting downward through plow pans but would be free of the undesirable features of subsoiling. The result was the development of a tillage method called slit-tillage and the development of various means of applying slit-tillage to crops or to individual plants. Slit-tillage is the cutting of a narrow. vertical slit through a compacted layer of soil. such as a plow pan. to promote rooting downward through the compacted layer into

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underlying soil. This paper is a review of slit-tillage research and a presentation of criteria that should be considered in developing slit-tillage implements and in applying slit-tillage

Materials and Methods

A number of field and greenhouse experiments were conducted to: 1. Evaluate the effectiveness of slit-tillage for promoting rooting downward through plow pans; 2. Evaluate the effect of slit-tillage on crop yield; 3. Establish specifications for slits; and 4. Investigate various means of cutting slits (Elkins 1980, Elkins et al., 1983, Van Sickle 1985, Reeves et al., 1988, Karlan et al., 1989. These experiments were conducted on Ultisols at Auburn, Headland, Shorter, and Crossville, Alabama and at Florence, South Carolina to compare slit-tillage to other tillage methods. Various implements such as vibratory cable-laying plows and modified subsoiler-planters as well as hand tools were used for cutting the slits. In the initial slit-till experiment slits were cut by hand with a long bladed spade (Elkins 1980.) The vibratory plows were equipped with blades that were about 5/32 inch thick and capable of cutting a slit from the soil surface to a depth of 15 inches. There was no surface tillage with these implements. A number of observation plots were planted to corn *(Zea mays* L.), grain and sweet sorghum *(Sorghum bicolor* L. Moench), okra *(Hibiscus esculentus* L.), peanuts (Arachis hypogaea L.), soybeans *(Glycine max* (L.) Merr.), and rape *(Brassica napus* L.) with a vibratory plow.

Two brands of subsoiler-planters were odified by shortening the subsoiler shanks and installing 5/32 inch thick blades that extended downward by about 7 inches from the lower end of the shanks. With these implements the subsoiler chisel point was run on top of the plow pan with the blade cutting a narrow vertical slit through the plow pan. A strip of surface soil up to 20 inches wide was tilled by the subsoiler chisel and by fluted colters attached to the shank or following the shank. Measurements of draft forces required to pull a subsoiler shank modified for slit-tillage were made in soil bins at the National Soil Machinery Tillage Laboratory (Elkins and Hendrick, 1983).

Greenhouse and field experiments were conducted to determine the optimum dimensions for the slits. Slits of various widths were formed in glass front boxes and soybeans were planted so that their roots would grow into the slits. In a companion field experiment various width slits were cut with a subsoiler shank equipped with 5/32, 1/4, 1/2, and 3/4 inch thick blades. Soybeans were grown above these slits. Observations of root growth were made in the boxes and by digging pits in the field plots.

Results and Discussion

Rooting

Roots of a variety of crop, vegetable, turf, and weed plants have been observed to grow vigorously in the slits. In fact, the roots of all plants observed responded positively to slits. Root elongation rates in slits by plants such as corn and soybeans has been observed to proceed at rates of about 2 inches per day. For example soybean roots reached the bottom of a fifteen inch deep slit while still in the cotyledon stage of growth. Rapid root growth in the slits would be expected since the two major factors that impede root growth in compacted soil, oxygen deficit and soil strength are eliminated by the slit. The walls of the slits are compacted so roots do not grow out the sides of the slits but are directed downward out the bottom of the slit into the subsoil. The tap roots or major lateral roots of tap rooted plants were observed to grow directly down the slit into underlying soil with branch roots forming a network of roots in the slit. Roots of fibrous rooted plants, such as corn and sorghum, filled the slit with a mat of roots, with the primary seminal and crown roots growing out the bottom of the slit.

Roots that grew in the slits. and residue from decomposed roots helped maintain the slits, and caused the slits to remain effective for several years. Root growth has been observed in slits that were five years old. Residue from roots that grew in slits in a Norfolk sand loam soil altered the chemical properties of soil in the walls of the slits in a way that should favor root growth. Van Sickle (1985) found increases in organic matter Ca, and Mg in the slit walls and a reduction in Al.

Yields

In the initial experiment soybean yields were 29, 25, and 18 bu/A for slit-tillage, complete surface tillage, and no-till respectively (Elkins 1980). Root observations from a pit dug across the rows showed that roots in the no-till plots were restricted to the surface soil by a plow pan but roots in the slit-tilled plots grew down the slit and proliferated throughout the subsoil to a depth of more than three and one-half feet. On plots where the surface was completely tilled rooting was more dense in the surface soil than on the no-till and slit-tillage plots, but few roots grew into the subsoil. During periods of low rainfall plants on plots with no slits wilted and on still, clear days leaf temperature of plants growing on slit-tilled plots was 4 to 5°F cooler than plants growing without slits.

In general, yields of soybeans and grain sorghum grown with slit-tillage have been greater than yields of these crops grown no-till or with complete surface tillage. In the first year of experiments, yields with slit-tillage were about the same as, but in some cases lower or higher than yields with in-row subsoiling. In the second year of experiments yields with slit-tillage equalled or exceeded yields with in-row subsoiling. By the third year yield with slit-tillage exceeded yields with in-row subsoiling (Elkins 1980, Van Sickleet al., 1984, Reeves et al., 1988, Karlan et al., 1989). The improved performance of slit-tillage with time is attributed to the cumulative effect of introducing additional, functioning slits each time slit-tillage is applied.

Slit Specifications

The roots of soybeans grown in slits in glass front boxes grew normally only in slits narrow enough so that the roots made good contact with both walls of the slits. Roots growing into wide slits ceased to elongate, sometimes producing many fine branches. This phenomena was verified in a field experiment where soybeans were grown over slits of varying widths. Contact with slit walls is essential for adequate water uptake. The ideal width for slits is one that is approximately the thickness of the root tip. For common tap-rooted plants this would be about 3/100 inch. The ideal width would vary with fibrous-rooted plants such as corn, sorghum, and millet.

From a practical standpoint a slit of acceptable width for both tap-rooted and fibrous-rooted plants can be obtained by cutting the slit with a blade ranging from 1/8 to 5/32 inch thick. In some cases a 3/16 inch thick blade may produce acceptable results, but caution should be exercised as thickness of the blade is increased. A blade thicker than that required for the slit can be used because elasticity ofthe soil and overburden weight ofthe soil tends to close the slit following passage of the blade.

Blades for cutting slits should be sharpened on the leading edge and **must be sharpened on the lower edge. A** sharpened or tapered lower blade edge is essential so that the bottom of the slit will be tapered. Upon reaching the slit bottom roots wedge themselves into the taper and can thus grow readily into the underlying soil. If slits have a flat or rounded bottom roots tend to grow along the slit bottom rather than penetrating into underlying soil.

An objective of slit-tillage is to establish stable slits. This can best be accomplished by cutting slits when the soil layer into which the slits are cut is wet (good plowing moisture content) so that the blade passing through the soil smears the slit walls. From a practical standpoint slits can be successfully cut only when the soil is wet because of increasing soil strength with drying and because of rapid wear of blades drawn through dry soil. As for blade length, blades should obviously reach through the plow pan and blades should initially be about 2 inches longer than required to allow for wear before replacement is necessary.

Implements

Effective slits have been cut through plow pans with a variety of implements ranging from a machete to four-row modified subsoiler-planters. Draft requirements for applying slit-tillage with a modified subsoiler shank was 12 to 43 percent lower than for subsoiling depending on operating speed and soil type. The 43 percent reduction was in Norfolk soil material with a speed near that of field operations. It appears that practical implements can be devised for application of slit-tillage with hand power, animal power, and with tractors ranging from small garden tractors to large farm tractors. The modified subsoiler-planter implements that have been used to experimentally apply slit-tillage are too heavy. The design and development of a slit-tillage-planter type implement is needed for successful application of slit-tillage to production agriculture. Implement development should also be considered for low power applications of slit-tillage, as with hand tools, garden tractors. and animal power.

Summary

Slit-tillage is a tillage procedure that installs narrow, vertical slits in compacted soil. The slits, if of proper dimensions, serve as substitutes for the macropores that are generally missing in compacted soil. The slits alleviate the oxygen deficiency and soil strength constraints on root growth that normally exist in compacted soils. A wide variety of fibrous and tap rooted plants responded favorably to slit-tillage. Roots grew in the slits at near maximum rates. On several experiments on southeastern soils (Ultisols), yields with slit-tillage were equal to, or exceeded yields with in-row subsoiling, complete surface tillage, and no-till. In the first year of some experiments yields with slit-tillage were slightly lower than yields with in-row subsoiling. Less power is required to slit*till than to subsoil to the same depth. Slit-tillage does not mix soil from different soil horizons as does subsoiling. The effect of slit-tillage last for several years in contrast to the usual short-term effects of subsoiling. Slit-tillage can he applied with a variety of implements, ranging from hand tools to large multi-row farm implements.

Conclusions

Slit-tillage is a useful procedure for ameliorating plow pans to promote rooting into the subsoil. In several ways slit-tillage is superior to other types of deep tillage. Implements should be developed specifically for slit-tillage so that it can be applied to production agriculture, to gardening, and to other plant growing enterprises.

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A Decade of Progress in Conservation Tillage in the South Carolina Coastal Plain

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Abstract

Conservation tillage (CT) in the South Carolina Coastal Plain began in earnest with development of in-row subsoil systems capable of planting into heavy plant residues. Problems associated with this development included reducing water loss from cover crops, improving stand establishment, assessing nutrient and water management requirements, determining optimal subsoiling strategies, understanding long term effects of CT on soil properties, effects of crop residue removal, and the interaction of CT tillage systems with pests and beneficial organisms. A concerted effort was initiated to study these interactions at the Coastal Plains Soil and Water Conservation Research Center in Florence, SC since the late 1970's. The findings of these studies published to date are summarized in this paper.

Introduction

Conservation tillage (CT) will be a key component of continued southern agricultural expansion (17). In the South Carolina Coastal Plain initial adoption of CT was impeded by problems associated with root penetration of the dense eluviated (E) soil horizons (11). Furthermore, dramatic increases in water infiltration and fertilizer retention, seen with CT in the hilly Piedmont, or in states like Kentucky, did not occur in the flat, sandy Coastal Plain. Success came only after an integral in-row subsoil/planting implement was developed (16). The Superseeder' allowed planting into crop residues or living mulches that were controlled with broad spectrum herbicides (paraquat or glyphosate). With initial rooting and weed problems solved, extensive applied and basic research was initiated at the USDA-ARS Coastal Plains Research Center to extend understanding of CT principles and their applications in the region

Review

Soil Water Content. Initial research focused on cover-crop water use because the CT system being promoted was spring planting of corn *(Zea may* L.) or soybean *(Glycine max* (L). Merr.) into a fall-planted rye *(Secale cereale* L.) cover crop. The rye, whose grain had little cash value, was often grazed in winter and the killed with paraquat at spring planting. The rye canopy abated soil loss from intense Spring rains but also severely desiccated the soil profile by evapotranspiration (ET) (9, 12). This often reduced corn yield, but had no negative effect on full-season, determinate soybean yield. The occurrance of more CT problems with corn than soybean was not anticipated from research in other regions (29) but was a consistent year-to-year response in the Coastal Plain (9, 12).

Initial studies attributed poor corn yield in CT plots to erratic emergence and slow early-season growth (24). The retarded plants ("corn weeds") robbed water and nutrients but remained barren. Low soil temperature caused similar problems at more northern latitudes (15), but this was not true in the Coastal Plain where temperature at 2- and 6-in depths were never more than 2^{o} F different for conventional and CT seedbeds. Water was hypothesized as the most limiting factor because many Coastal Plain Ultisols retain less than 4in. of plant available water per 3 ft of profile (I). Furthermore, even though surface residues can conserve several days equivalent ET by reducing soil evaporation during the growing season. this gradual benefit did not overcome early-season profile depletion and growth retardation in corn.

Determinate soybean yields were not reduced by cover cropping or CT, if full canopy cover occurred by flowering. If prolonged drought occurred in soybean during the reproductive period, CT increased yields slightly compared with conventional tillage, depending upon the timing of the dry period relative to length of the reproductive period. An effective management solution to the problem of cover crop water use was to kill the cover crop 2 to 3 wk before planting corn or soybean. This halted soil water extraction, providing an opportunity for soil profile recharge (9, 12, 20).

One approach to eliminating high soil strength involves managing soil water content. However, to overcome strength limitations for the high bulk densities of typical Coastal Plain soils risks maintaining water contents which limit root oxygen availability (10). Recent work with sweet corn showed that the approach can work, but only with a high level of management (7).

Subsoiling. Another applied CT study showed that for South Carolina Coastal Plain soils, in-row subsoiling and irrigation resulted in additive yield benefits forcom (6), even though water was supplied by irrigation. This occurred because sandy surface soils allowed N, K, S, and B to leach to the Bt horizon (23). Subsoiling facilitated deeper and earlier root penetration which promoted more efficient use of these nutrients from the B horizon where they occur in greater abundance, see Figure I. In-row subsoilers were also used for direct fertilizer placement behind the subsoil shanks without requiring knives or disks on which surface trash is easily entangled (25). This produced yields equivalent to traditional 2 in. by 2 in. placement.

Energy costs in the late 1970'scaused fanners to question the need for annual subsoiling. The persistence of subsoil disruption was evaluated for several deep tillage methods (4). In-row subsoiling was more effective than disking, chiseling, and mold-board plowing for reducing soil strength to the B horizon which has a higher clay content and water

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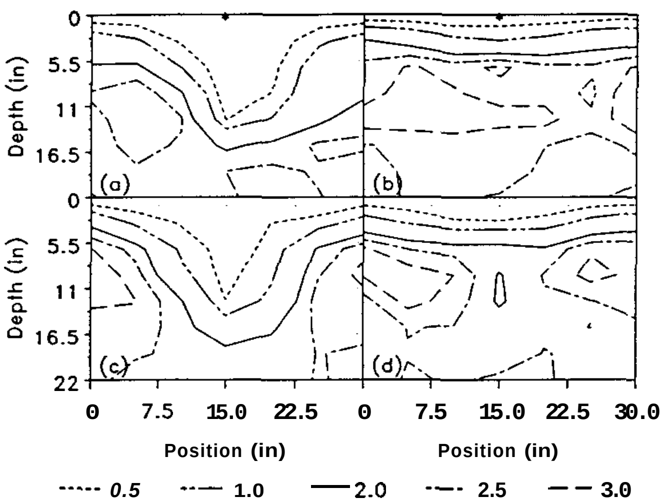

Figure 1. Soil strength contours that show breaking up of the 6- to 14 in deep E horizon by the Superseeder in April (I) soon after the deep tillage and in August (c), compared to disked plots in April (b) and August (d). Some remnanats of deep tillage from previous years can be seen in the disked plot. * indicates the row position.

holding capacity. Although, using a penetrometer, the location of a subsoiling operation was identifiable after 2 yr. none of these implements maintained cone indices below recognized limits to rooting for more than one year (31). Furthermore, without precise traffic control, planting over the previous season's subsoiling was not possible. Another study showed that rather than alleviating physical and nutrient problems, complete mixing of the A and B horizon exacerbated both of these problems because of the acidity, nutrition, and void ratio of the resulting media. (8).

As in-row subsoiling became more universally adopted in the Coastal Plain, several implements became available for use in CT. Though the deep disruption patterns for the Brown-Harden Superseeder, the Tye Paratill, and the Kelly No-till System and their draft requirements varied (T.H. Garner, personal communication), they all shattered the E horizon to non restricting cone indices. Despite differences in the overall soil profile strengths (see Table I), yield differences among plots treated with the implements were not significant (2). Another promising tool was described which slits shallow tillage pans (13). Here, a thin blade cuts a 0.15 in wide slit (about the size of a macropore) through the hard layer. Crop roots stabilize the slit and maintain it for several years. Where the layer of high strength is deeper, this blade is attached to the bottom of a short subsoil shank, using less horsepower than unaided deeper shanks. These slits have been found 3 yr after they were cut. Plots that were annually slit outyielded standard in-row subsoiled plots after 2 yr of slitting (22).

Soil Strength. Establishing CT has been difficult in areas where soils easily compact. Coarse textured Ultisols with low organic matter required less compactive force to produce high bulk densities and high probe resistances (5, 30). Relating strength to hulk density and water content also depends on texture and organic matter. Making field strength comparisons is complicated by water content and bulk density variability, requiring mathematical techniques to assess absolute strength differences. Sophisticated statistical and mathematical techniques were developed to make these comparisons (3, 28), reducing treatment confounding effects such as strength dependence on measurement date, treatment location, or water regime. These techniques were utilized to show that in-row subsoiling was more effective than conventional tillage when combined with CT (3).

Table 1. Mean profile soil strengths for disked and minimum tillage plots subsoiled with the Superseeder (SS), Paratill *(PT)*, and Kelly (KE).

Residue Mngmt	SS	PT	KE	Mean
	Implement			
	(MPa)			
Disked	6.18	5.68	5.22	5.69
Mintill	5.48	5.58	5.40	5.49
Mean	5.83	5.63	5.31	

Soil Biota. In addition to physical, chemical, and environmental aspects of CT pest management techniques were also unknown. Crop residue removal and tillage affected four nematode species *(Meloidogyne incognita, Scutellonema brachyurum. Pratylenchus scribneri,* and *Paratrichodorus christiei)* differently (14). *Meloidogyne incognita* and *P. christiei* populations were not significantly affected by tillage, but *S. brachyurum* populations were highest in CT treatments where crop residue was not removed. In contrast, *S. brachyurum* populations were lowest in CT plots where 90% of the crop residues were removed or incorporated. In insect studies emergence of *Heliothis* species was reduced by tillage. Compaction without tillage stabilized insect burrows; compaction after tillage sealed the burrows and damaged the pupae (26, 27). Therefore, less intensive tillage treatments had greater emergence.

Conservation tillage also affects the environment of beneficial organisms. The success of soybean depends greatly on providing a suitable environment for the symbiotic interaction of soybean and Bradyrhizobium japonicum. Despite subtle tillage x strain x cultivar interactions that affected nodular occupancy and N_2 fixation by specific cultivar and strain combinations, yield was not affected (19). In a related greenhouse experiment in which understory surfaces were varied independently from soil properties, early stem growth was greater for a straw-covered surface than for a bare surface. but nodulation was unaffected (18).

For sandy Coastal Plain soils, increased organic matter can improve both water and nutrient retention, enhancing productivity. Long-term effects of CT on several soil-test parameters were examined after eight years. In the upper 8 in, there was a trend toward, but not a significant increase of, CT Mehlich I soil test values over disked treatments. There was, however, an increase of organic carbon over the eight years from 0.5 to 1.0%. for the disked treatment and from 0.5 to 1.2% for CT (21).

Conclusion

The Coastal Plains Soil and Water Conservation Research Center in Florence, SC exerted a concentrated effort at understanding the advantages and shortcomings of CT for that region of the country. This included the interaction of CT with water loss from cover crops, stand establishment, water and nutrient management, soil strength management through deep tillage or intensively managed irrigation, crop residue removal, long term effects on soil properties, and pests and beneficial organisms. Understanding these effects on conservation tillage has helped make CT a more viable management alternative in the SC Coastal Plain.

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Effect of Intensive Cropping on Nematode Population Management

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Abstract

Plant-parasitic nematodes cause losses that exceed $5 billion annually on field crops, fruit and nut crops, vegetable crops, and ornamental crops in the United States. Nematicides have been a major tool used in managing nematode populations for over 35 years. The impact of the loss of the most effective soil fumigants and the environmental concerns about nonvolatile nematicides is being felt by growers, and the impact will probably increase since available nematicides are more costly and less effective. Alternative integrated systems utilizing intensive cropping, tillage methods, non host crops, resistant cultivars, trap crop, minimal use of nematicides, and other strategies are needed to manage nematode population densities on crops. Research results on new alternative systems for managing nematode populations in intensive cropping systems under irrigated conditions at the Coastal Plain Experiment Station will be discussed.

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Starter N-P-K Combinations Effect On No-Tillage Cotton

D.D. Howard and P.E. Hoskinson[1]

Abstract

Little information is available concerning starter applications for no-tillage cotton (*Gossypium hirsutum* L.). This study was conducted to evaluate N-P-K starter combinations on no-tillage cotton. Research was conducted at two locations for four years (5-site years) on a Memphis silt loam (Typic Hapludalf). A randomized complete block with treatments replicated five times was utilized at each location. Eight treatments were evaluated in 1985 but were expanded to ten in 1986. Broadcast fertilization rates were either 60-30-30 or 30-30-30 lb/A N-P_2O_5-K_2O, respectively. Equivalent nutrient rates were applied as a band plus broadcast combination. Banded treatments included 15-0-0, 30-0-0, 15-8-0, 15-15-0, 15-30-0, 30-15-0, and 15-15-15 lb/A N- P_2O_5-K_2O, respectively. Yields varied with year, treatment, and location. One or more banded treatments significantly increased lint yields when compared with the broadcast yield, except in 1987. In 1985, banding 15-0-0 and 15-15-0 increased yields 159 and 102 lb/A, respectively. Banding 30-0-0 and 15-15-0 in 1986 increased yields 186 and 183 lb/A, respectively. Banding 15-30-0 in 1988 at Milan increased yields 116 lb/A. Banding 15-15-0 in 1988 at Ames increased yields 125 lb/A. Dryer than normal weather conditions in 1987 and 1988 may have affected fertilizer placement. Cotton was planted and treatments applied to a hot dry seed bed in 1987. The dry weather in late May and June may also have affected treatment effects during 1988.

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Strip-Till and No-Till Demonstrations In North Alabama, 1985 to 1988

D.P. Delaney[1]

Abstract

Cotton has been successfully grown with conservation tillage in small-plot research in North Alabama, however, farmer adoption of this practice has been slow. This may be due in –part to traditional attitudes about clean-farming and previous failed attempts by some innovators. In 1985, an intensive program of reduced-tillage cotton demonstrations was begun to: 1) Demonstrate application of successful small-plot results to producers on a field-sized (5-20 A) basis, and 2) Test and refine emerging technology for practical on-farm use. Thirty-three on-farm demonstrations utilizing several types of residue and planting techniques were conducted from 1985 to 1988. Generally, demonstrations on "red-land" (deep clay-loam soils), have met with limited success. Economical weed control has been difficult to attain on many of these fields because of limited rotation, and resulting buildup of weeds resistant to the limited selection of herbicides available. Surface compaction, seedling diseases, and problems with applying any corrective in-row tillage have all contributed to a lack of clear benefit, and some yield reductions from conservation tillage on these soils. Results on "Sand Mountain" soils (shallow sandy-loam), have been much more promising. Increased moisture conservation and availability on these soils (with low inherent moisture-holding capacities), resulting from the use of in-row subsoiling and other minimum-till methods, has consistently resulted in better late-summer growth, and production of 50-150 #/A more lint over conventional tillage. Areas still needing to be addressed include consistent and economical weed control, the need for deep tillage and cultivation on particular soils, and seedling disease control.

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