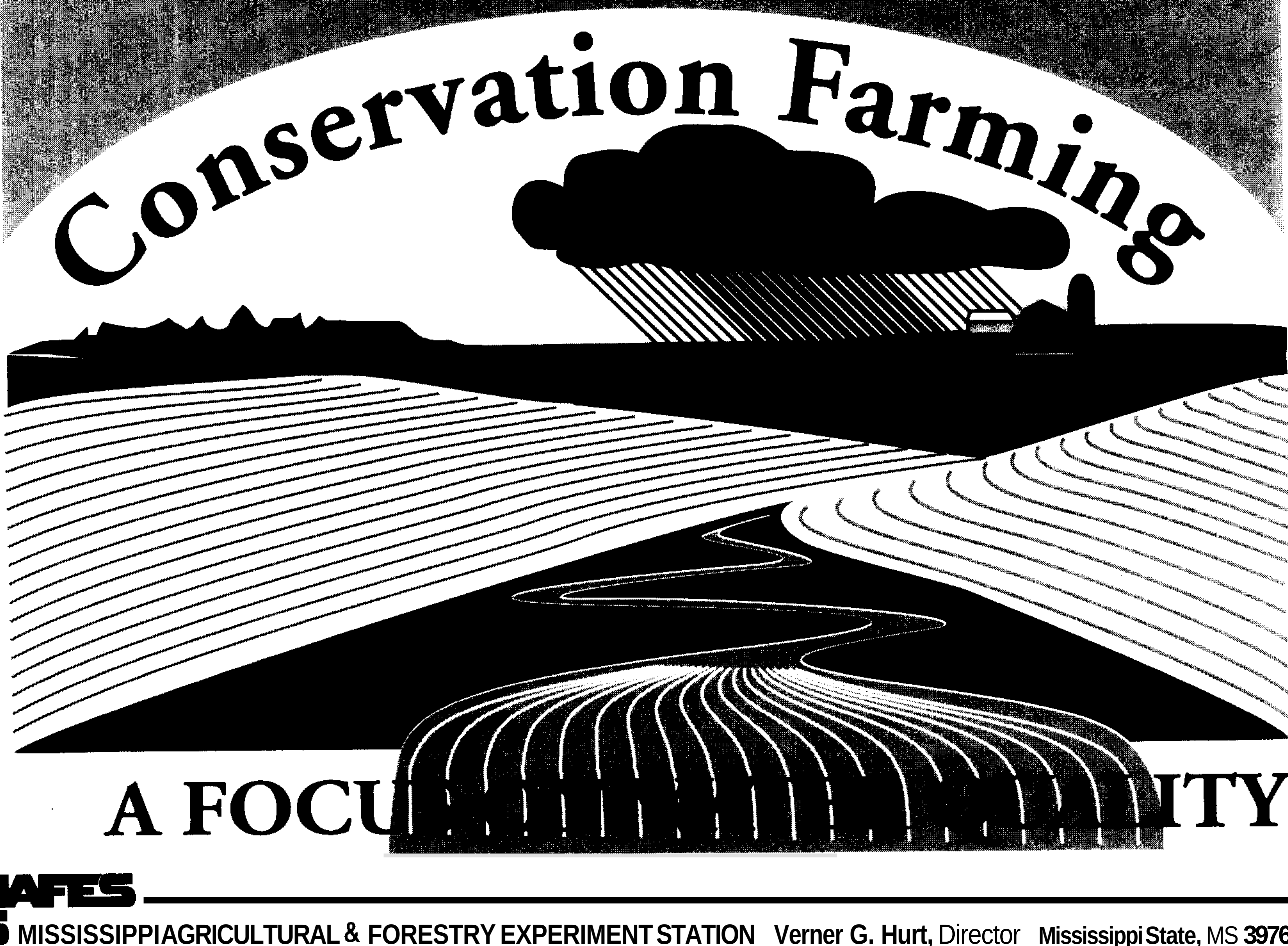

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Proceedings

1995 Southern Conservation Tillage Conference for Sustainable Agriculture

Jackson, Mississippi
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Conservation Farming
A Focus on Water Quality

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Foreword

Following the 1987 No-Till Conference name change, Mississippi hosted the first newly named Southern Conservation Tillage Conference, the aptly chosen theme of which was “Conservation Farming: A Focus on a Better Future.” The 1988 theme provides a segue to the 1995 theme, “Conservation Farming: A Focus on Water Quality.” Coupling the terms of conservation farming and water quality captures the essence of the Conference’s long-standing commitment to promote the study and use of farming practices aimed at achieving viable agricultural productivity and conservation of soil and water resources.

A brief trip back to the future serves as a reminder of the recognition by ancient farming societies of the value of conservation farming practices, a concept which is now a rapidly developing arena for the potential application of recent technologies, such as satellite-assisted farm management based on site-specific soil properties. The timeless appeal of conservation farming can be attributed, in the main, to its amenability to the application of principles of scientific inquiry. This has permitted an ever-improving understanding of the relation of underlying natural processes to agricultural production, and positive or negative changes in the status of soil and water resources. From this foundation has sprung the potential for reduced economic requirements and optimization of desired outcomes in farm productivity and environmental quality.

Farmers and farm managers have been made keenly aware that a better future for farming is intimately linked to society’s focus on water quality — and that the future is now. Mississippi is proud to host this year’s conference, the purpose of which is to convey, in a useful format, the results of scientific experimentation and observation that help provide the means by which the goals of conservation farming and society may be closely aligned. .

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ORAL PRESENTATIONS

Interactive Effects of Wheel Traffic and Tillage System on Soil Carbon

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Introduction

The carbon-conserving nature of reduced or no-till soils as compared to conventionally tilled soils is well documented (Blevins et al., 1983; Havlin et al., 1990; Wood and Edwards, 1992). With no-till, plant residues remaining on the soil surface decompose more slowly, resulting in more carbon (C) being retained in the soil than when residues are incorporated into the profile (Holland and Coleman, 1987).

The negative effects of soil compaction on plant growth have been attributed primarily to a restriction of root growth. It has been suggested that soil compaction could affect the size and activity of the microbial biomass, and therefore, result in changes in cycling patterns of nutrients needed for plant growth (Griffin, 1978; Dick et al., 1988).

Soil compaction may affect microbial biomass dynamics via changes in available pore space (Dick et al., 1988). These microbial shifts lead to changes in rates of decomposition and mineralization of nutrients into plant available forms. However, there remains a lack of research investigating the biological effects of soil compaction and its interaction with tillage systems. The purpose of this study was to determine seasonal changes occurring in the cycling of C caused by to tillage and compaction.

Materials and Methods

This study was part of a continuing long-term (initiated in 1987) project designed to determine the interactive effects of tillage method and wheel traffic (compaction) on crop yields, crop quality, and soil properties. The study site soil is a Norfolk loamy sand (fine, loamy, siliceous, thermic Typic Kandiudult) located at the E. **V.** Smith Research Center of the Alabama Agricultural Experiment Station near Shorter, Alabama. Tillage and compaction treatments initiated in 1987 include conventional tillage (disk/field cultivate) and no-tillage, and wheel traffic or no-traffic, respectively. The experimental design is a randomized complete block with four replications arranged as a split plot. Wheel-traffic treatments are main plots, and tillage treatments are subplots.

The cropping system at the study site is a corn *(Zea mays* L.) 'Dekalb 689'-soybean *[Glycine max* (L.) Merr.] 'Delta and Pineland 105' rotation with crimson clover *(Trifolium incarnutum* L.) as a winter cover crop. The study reported here was conducted during June 1993 to June 1994 to determine seasonal dynamics of soil organic C, respiration, and microbial biomass C as impacted by tillage system and compaction. Soybean was the summer crop of 1993, followed by a winter crimson clover crop. Corn was the summer crop of 1994.

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Field activities were carried out using an experimental wide-frame tractive vehicle (WFTV) (Monroe and Burt, 1989). The WFTV spans the 6.1-m wide research plots and performs field operations without applying traffic to the plots. To simulate normal wheel traffic on trafficked plots, a 4.6-Mg tractor was utilized. The tractor was driven in trafficked plots during spring field preparation and planting, simulating operations used by a grower employing four-row equipment, i.e., every other row received wheel traffic.

Soil samples (0-20 cm depth) were collected biweekly during the growing season and monthly during the winter months for determination of microbial biomass C (Vance et al., 1987). Organic C was determined with a LECO CHN-6OO analyzer on soil samples (0-20 cm depth) collected in July and October of 1993, and in January and May of 1994. All samples or measurements were taken in row middles, and measurements made in trafficked plots were taken in row middles that had received wheel traffic.

Soil respiration was measured biweekly during the growing season and monthly during the winter. Four measurements were taken per plot. Respiration was measured using an Environmental Gas Monitor (EGM) (PP Industries Stotford, Hitchin, Gertts SG5 4LA UK). Analyses of variance were performed using the SAS package (SAS Institute, 1988). Because time was a factor, data were analyzed as a split-split plot with wheel traffic as main plots, tillage as subplots, and time as sub-subplots. All statistical tests were performed at the $a=0.05$ level.

Results and Discussion

After 6 years of tillage and traffic treatments, over all sampling dates, there were no significant differences in organic C concentrations attributed to tillage or wheel traffic (data not shown). This is contrasted by findings of a study conducted by Wood and Edwards (1992) in northern Alabama, which showed higher levels of soil organic C with reduced tillage (0-10 cm). Our findings also differ from those of Dick et al. (1988), who showed significantly lower levels of organic C (10-20 cm) as a result of compaction in skid trail soils.

Microbial biomass C (MBC) levels were significantly affected by the interaction of traffic, tillage, and sampling date (Figure 1). Data from this study suggest a trend for higher levels of MBC from conventional tillage (CT) than from no-tillage (NT) (Figure 1). However, there was no consistent effect observed from treatment interactions on MBC, except on sampling dates immediately following tillage (Figure 1).

Five measurements were taken in the 3 weeks immediately following tillage and traffic events to investigate immediate effects of tillage and compaction on MBC. Tillage method had a significant effect on MBC during 1994 field operations (Figure 2). CT soils had significantly higher levels of MBC than NT soils (Figure 2). Before wheel-traffic application, CT in combination with traffic (TRAF) had highest MBC levels immediately following tillage (Figure 2). Five and nine days later, MBC from the CT-TRAF treatment remained highest, though the difference was not significant (Figure 2). These results are similar to findings of Lynch and Panting (1980), who found higher microbial biomass (0-5 cm) following tillage compared to NT. However, their study showed higher microbial biomass from NT compared to CT during all other sampling dates in the 0-5 cm depth.

A study conducted by Dick et al. (1988) showed that compaction results in decreased MBC (10-20 cm). However, results from MBC measurements taken during our study have shown no detrimental effects on MBC owing to compaction. Biomass C has been shown to have significant negative correlations with bulk density (Dick et al., 1988). Van der Linden et al. (1989) found soil compaction to result in decreased available pore space, which slows the rate at which organic substrates are incorporated into and released from microbial biomass, on a silt loam soil but not on a loamy sand. Even though bulk densities from TRAF soils were significantly higher than nontrafficked (NONTRAF) soils in our study (data not shown), it appears that soil texture (loamy sand) played a significant role in lack of effects from compaction on MBC. Because of the coarse texture of this Coastal Plain soil, available pore space was apparently not decreased enough to affect MBC.

Soil respiration was significantly affected by tillage and there was a trend for a wheel-traffic effect. Conventional tillage soils had significantly higher rates of soil respiration than NT soils on many measurement dates (Figure 3). There was a trend for a traffic to decrease soil respiration, but response was dependent on time of wheel-traffic application.

In this study, soil respiration was stimulated by tillage, but CT soils maintained a higher level of soil respiration than NT soils over most of the observation period (Figure 3). Higher rates of soil respiration (C mineralization) from CT soils compared to NT soils should result in higher levels of organic C being retained in NT soils. However, as previously discussed, there were no significant differences in organic C between CT and NT soils.

Eight soil respiration measurements were taken immediately encompassing tillage and traffic events to monitor direct effects of tillage and traffic on soil respiration. Equipment failure delayed the first measurement to 6 days after tillage had occurred . Soil respiration was influenced by a significant traffic x tillage x measurement date interaction. A large flush of CO_2 was observed 8 days following the tillage operation and 2 days following wheel-traffic application for the

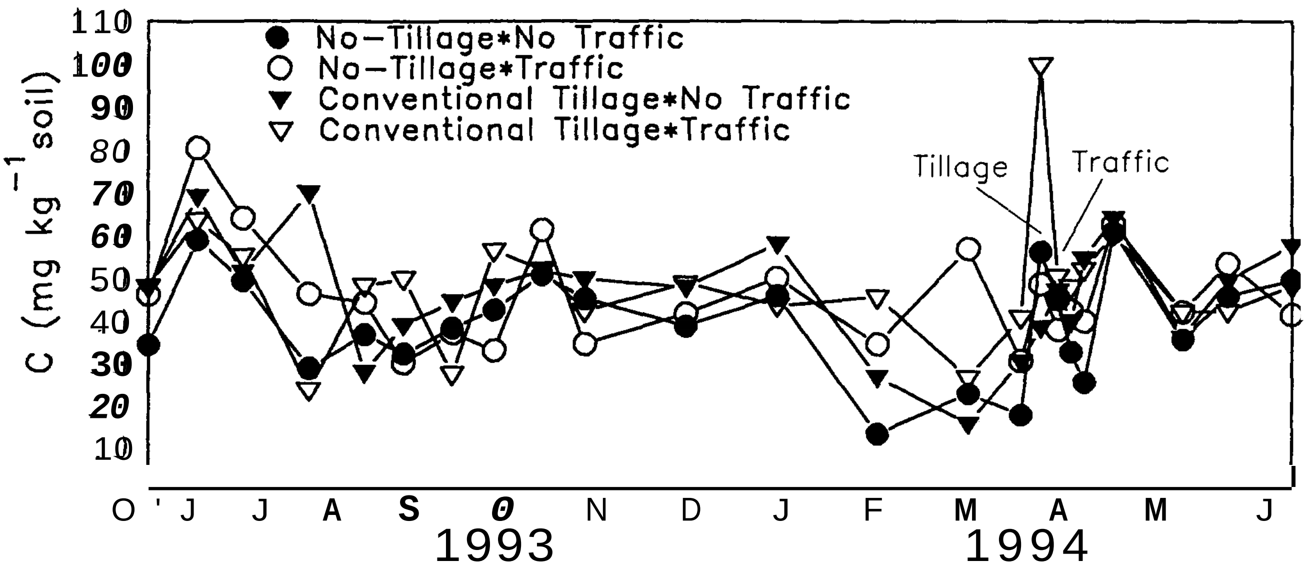

Figure 1. Microbial biomass C concentrations as affected by traffic, tillage, and sampling date for 1993-1994. $LSD_{0.05}$ =260 for comparison of two traffic means at the same combination of tillage treatment and day. $LSD_{0.05}$=25.1 for comparison of two tillage means at the same combination of traffic treatment and day. $LSD_{0.05}$=24.1 for comparison of 2-day means at the same combination of traffic and tillage.

CT soils (Figure 4). This flush fluctuated but remained significantly higher than that observed in NT soils. These results agree with the hypothesis of Blevins et al. (1984) concerning the immediate effect of tillage, but soil respiration was equal or higher from CT soils compared to NT soils over the remainder of the observation period (Figure 3).

Compaction was expected to slow soil respiration, but on these soils the effect of compaction appeared to be dependent on measurement date. Mean bulk density was 1.61 Mg m^{-3} for CT-TRAF soils and 1.32 Mg m^{-3} for CT-NONTRAF soils. In September 1993, CT-NONTRAF soils had a higher rate of soil respiration than CT-TRAF soils (Figure 3). This also occurred 5 days after traffic was applied and again in June 1994 (Figures 3 and 4). Immediately following the April 1994 wheel-traffic application, soil respiration was significantly higher from CT-TRAF soils compared to CT-NONTRAF soils (Figure 4). Soil respiration was significantly higher from CT-TRAF soils than CT-NONTRAF soils 2, 3, and 7 days after traffic application, but **5** days after traffic there was a large flush of CO_2 from CT-NONTRAF soils (Figure 4).

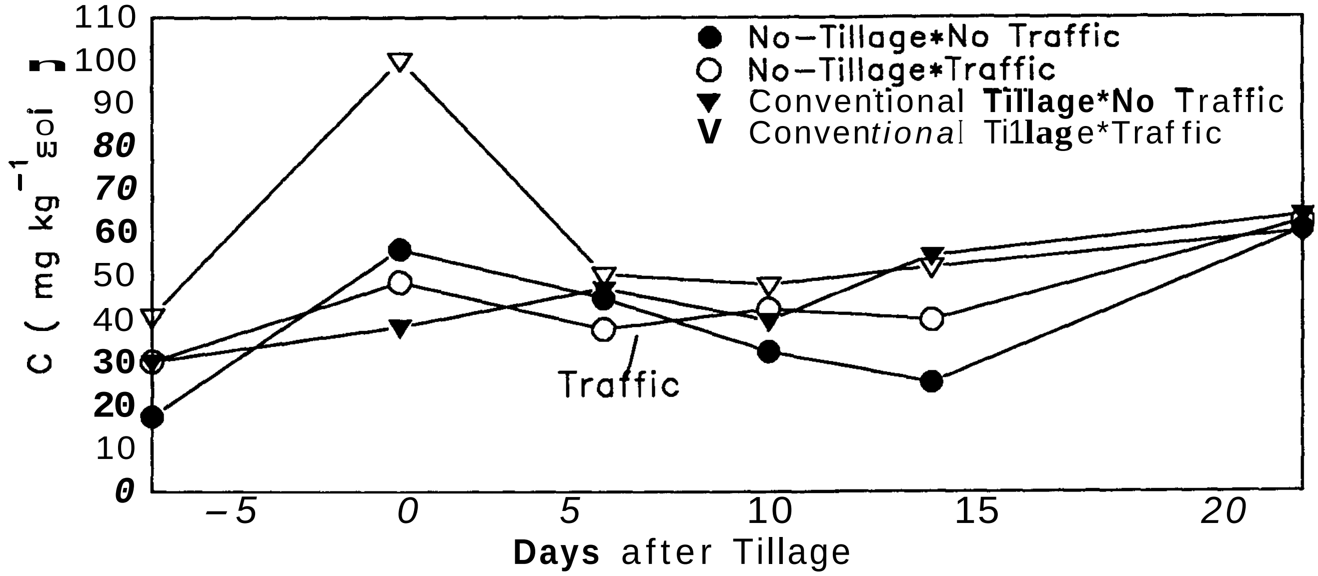

Figure 2. Microbial biomass **C** concentrations as affected by traffic, tillage, and sampling date during 1994 tillage and wheel-traffic operations. **$LSD_{0.05}$=31.6** for comparison of two traffic means at the same combination of tillage treatment and day. **$LSD_{0.05}$=24.6** for comparison **of** two tillage means at the same combination of traffic treatment and day. **$LSD_{0.05}$=25.2** for comparison **of** 2-day means at the same combination of traffic and tillage treatments.

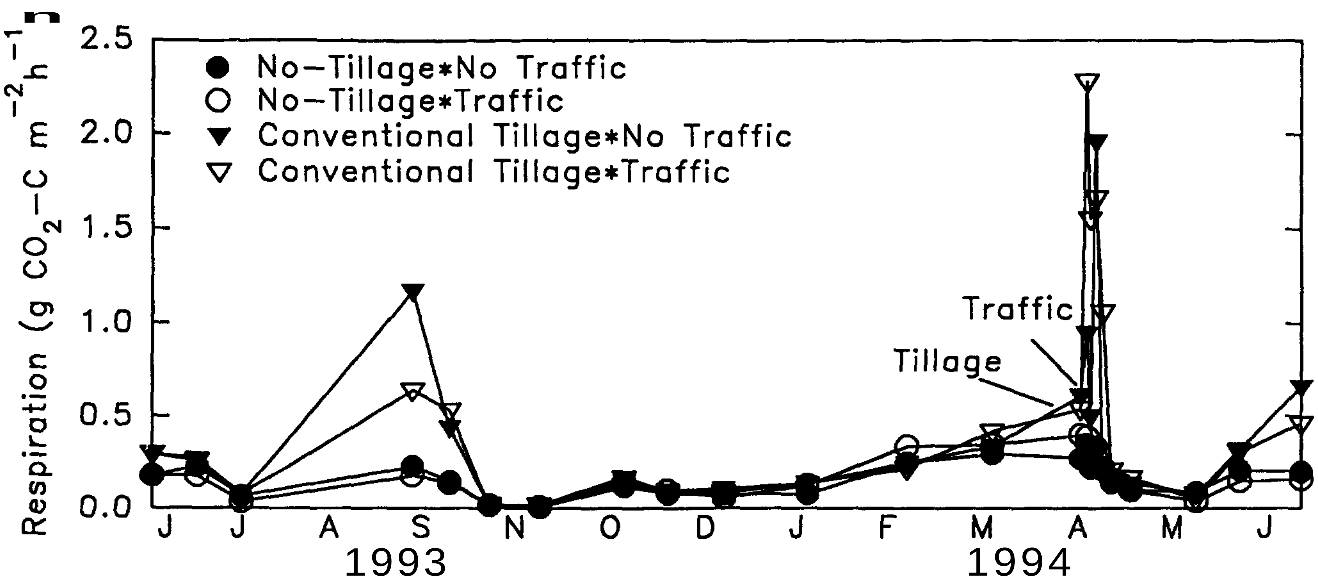

Figure 3. Soil respiration rates **as** affected by traffic, tillage, and sampling date for 1993-1994. **$LSD_{0.05}$** =0.18 **for** comparison of two traffic means at the same combination of tillage treatment and day. **$LSD_{0.05}$=0.17** for comparison of two tillage means at the same combination of traffic treatment and day. **$LSD_{0.05}$=0.17** for comparison of 2-day means at the same combination of traffic and tillage.

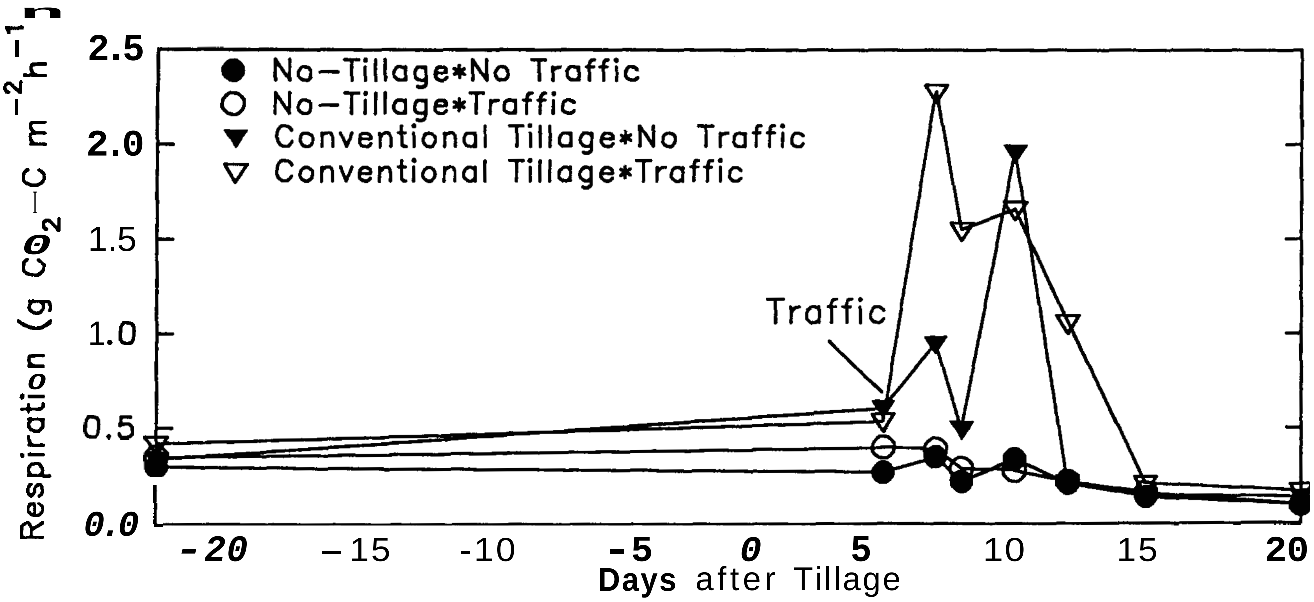

Figure 4. Soil respiration rates as affected by traffic, tillage, and sampling date during 1994 tillage and wheel traffic operations. $LSD_{0.05}$ =0.29 for comparison of two traffic means at the same combination of tillage treatment and day. $LSD_{0.05}$=0.25 for comparison of two tillage means at the same combination of traffic treatment and day. $LSD_{0.05}$=0.21 for comparison of 2-day meam at the same combination of traffic and tillage treatments.

It appears that immediate traffic effects on microbial activity had decreased or disappeared by 10 to 15 days after wheel traffic was applied. Soil respiration could have been increased in CT-TRAF soils via increased soil-substrate contact. The flush of microbial activity that occurred 11 days after tillage from CT-NONTRAF soils (Figure 4) could have resulted from incorporation of organic substrates. This flush may have been delayed compared to CT-TRAF soils because there was a lack of traffic induced contact with soil microorganisms.

Conclusions

Although respiration was significantly greater from CT soils than from NT soils, soil organic C was unaffected by tillage or traffic treatments. Microbial biomass C showed no consistent effect attributable to traffic and tillage treatments, which agrees with organic C data. Both tillage and wheel traffic stimulated soil respiration during April 1994 field operations, but wheel traffic did not cause increased soil respiration during other measurement periods as did tillage.

Surprisingly, compaction due to wheel traffic had no negative effect on microbial biomass carbon. It is believed that the coarse texture of this Coastal Plain soil played a significant role in the lack of negative impacts due to traffic-induced compaction on soil C.

References

Blevins, R.L., G.W. Thomas, M.S. Smith, W.W. Frye, and P.L. Cornelius. 1983. Changes in soil properties after 10 years continuous non-tilled and conventionally tilled corn. Soil Tillage Res. 3:135-146.

Blevins, R.L., M.S. Smith, and G.W. Thomas. 1984. Changes in soil properties under no-tillage. *In* R.E. Phillips and S.H. Phillips (eds.), No-tillage agriculture: principles and practices. Van Nostrand Reinhold, New York, pp.190-230.

Dick, R.P., D.D. Myrold, and E.A. Kerle. 1988. Microbial biomass and soil enzyme activities in compacted and rehabilitated skid-trail soils. Soil Sci. SocLAm. J. 52:512-516.

Griffin, D.M., 1978. Water Potential as a selective factor in the microbialecology of soils. *In* J.F. Parr et al., (eds.), Water potential relations in soil microbiology. p. 141-151. Soil Sci. S o cAm. Spec Publ. No. 9.

Havlin, J.L., D.E. Kissel, L.D. Maddux, M.M. Claassen, and J.H. Long. 199O. Crop rotation and tillage effects on soil organic carbon and nitrogen. Soil Sci. S o cAm. J. 54~448-452.

Holland, E.A., and D.C. Coleman. 1987. Litter placement effects on microbial and organic matter dynamics in an agroecosystem. Ecology. 68~425-433.

Lynch, J.M., and L.M. Panting. 1980. Cultivation and the soil biomass. Soil. Biol. Biochem. 12:29-33.

Monroe, G.E., and E.C. Burt. 1989. Wide frame tractive vehicle for controlled-traffic research. Appl. Eng. Agric 5:40-43.

SAS Institute, Inc 1988. SAS/STAT User's Guide, Release 6.03 Edition. SAS Institute, Inc., Cary, NC.

Vance, E.D., P.C. Brookes, and D.S. Jenkinson. 1987. An extraction method for measuring soil microbial biomass C. Soil Biol. Biochem. 19:703-707.

van der Linden, A.M.A., L.J.J. Jeurissen, J.A. van Veen, and B. Schippers. 1989. Turnover of the soil microbial biomass as influenced by soil compaction. *In* Jens AA. Hansen and K. Henrikson (eds.), Nitrogen in organic wastes applied to soils. Academic Press Inc, San Diego, CA. pp. 25-36.

Wood, C.W., and J.H. Edwards. 1992. Agroecosystem management effects on soil carbon and nitrogen. Agric Ecosystems Environ. 39~123-138.

Poultry Litter Nitrogen Utilization by Eight Grass Species

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Introduction

Several studies have been conducted on nitrate contamination of water by feedlots and commercial fertilizers (McLeod and Hegg, 1984; Khaleel et al., 1980; Sommerfeldt et al., 1973; Lorimar et al., 1972), while limited research has been conducted on land-applied poultry litter and its effects on groundwater (Giddens and Barnett, 1980; Liebhardt et al., 1979).

Nitrate contamination of groundwater is an important concern for agricultural and nonagricultural industries and the general public. Certain agricultural practices are identified as contributors to nonpoint source pollution (Daliparthy et al., 1994). The ultimate receptor of animal wastes is adjacent agricultural land (Loehr, 1970). Estimates as high as 73% of all manures from confined production are land-applied (Stewart, 1980).

Land-applied poultry litter may be used as a crop fertilizer, which tends to limit the problems associated with litter accumulation. Poultry litter has beneficial impact on yield of tall fescue *(Festuca arundinacea* Schreb.) (Hunneycutt et al., 1988), orchardgrass *(Dactylis glomerata* L.) (Hileman, 1973) and bermudagrass *[Cynodon dactylon* (L.) Pers.] (Hunneycutt et al., 1988).

The objectives of this study were to evaluate the effects of poultry litter application on dry matter (DM) yield, nitrogen (N) accumulation in plant tissue, and nitrate nitrogen (NO,-N) concentrations in soil water.

Methods and Materials

This study was initiated at the Natural Resources Conservation Service (NRCS) Plant Materials Center at Booneville in west central Arkansas. The study was conducted on a Taft silt loam (fine-silty, ciliceous, Thermic Glossaquic Fradiuoults) soil. Main plot treatments with three replications consisted of a control (0), 4, and 8 tons of poultry litter/acre on a dry-weight basis. The 4 ton/A poultry litter rate was broadcast-applied as a single application in April and October for the warm- and cool-season grass species, respectively. The 8-ton litter rate was applied as two 4-ton/A split applications in April and June for the warm-season species and October and April for the cool-season species. Nutrient analysis of the poultry litter was approximately 80.1, 68.8, and 54.3 lb/ton for nitrogen, phosphorus, and potassium, respectively.

Individual grass and fallow subplot sizes were 10 by 20 feet. Warm-season perennial grass species included 'Alamo' switchgrass *(Panicum virgatum* L.), 'T-587' Old World bluestem *(Bothriochloa caucasica* C. E. Hubb.), 'Pete' eastern gamagrass *[Tripsacum dactyloides* (L.) L.], and 'Midland' bermudagrass. Cool-season perennial species consisted of 'Palaton' reed canarygrass *(Phalaris arundinacea* L.), 'Martin' tall fescue, and 'Boone' orchardgrass.

A cool- and warm-season annual subplot included a combination of 'Marshall' ryegrass *(Lolium multiflorum* Lam.) and 'Elbon' rye *(Secale cereale* L.) planted in early fall and a forage sorghum *[Sorghum bicolor* (L.) Moench] planted in early summer. Establishment seeding rates for subplots were based on NRCS and University of Arkansas Extension Service recommendations. A 4.5-inch row spacing was used for seeded species. Bermudagrass was vegetatively established and sprigged on 1-foot centers. Eastern gamagrass seed was germinated in a greenhouse and transferred to subplots with a 1.5-foot row spacing and a 1-foot spacing between plants within the row. Cool-season perennials were seeded in March of 1992 and warm-season perennials were established mid-June 1992.

Litter was applied to the cool- and warm-season fallow subplots at the same rate and on similar dates as the grass subplots. The fallow plots were maintained free of plant material throughout the study.

Harvest regimes for seasonal distribution and total dry matter production were based on best management practices for maximizing production and/or hay production for individual grass species. Clipping height for grass species were: 6 inches for switchgrass, 4 inches for Old World bluestem and sorghum, 8 inches for eastern gamagrass, 2 inches for bermudagrass, and 3 inches for tall fecue, orchardgrass, reed canarygrass, rye, and ryegrass.

After each harvest, randomly collected samples were obtained for tissue analysis. The samples were dried at 140°F and ground in a Cyclotec sample mill (Tecator, Hoganas, Sweden) using a 0.5-mm screen. Tissue Kjeldahl N accumulation for the different grass species was calculated on an oven-dry weight basis.

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In May 1993, porous ceramic tip soil moisture samplers (Soil Moisture Equipment, Santa Barbara, CA, Model No. 1920) were installed at a depth of 18 inches. A 2-inch mechanical auger was used to install the samplers at the desired depth. A small quantity of bentonite clay was added to the hole to isolate the samplers from the soil below. Similarly, a small amount of pure silica-sand (200-mesh) was added and the sampler inserted into the hole. Silica-sand was then added to an approximate 6-inch depth. Extracted soil was added to a level above the soil moisture sampler and a bentonite plug was used to isolate the samplers and ensure against water channeling into the hole. The remainder of the hole was backfilled with soil while tamping out continuously with a metal rod.

A vacuum was drawn on soil moisture samplers prior to water collection. Rainfall events dictated sampling frequency. Sampling occurred once a month from November through May of each year. Water was then stored until nitrate N and phosphorus were analyzed on each sample.

Results and Discussion

Seasonal DM yield (Table 1) for the observed grass species ranged from 1,660.0 to 10,765.3 lb/A for the control (zero litter); 4,840.8 to 22,932.3 lb/A for the 4-ton/A litter application; and 7,387.0 to 26,903.9 lb/A for the 8-ton/A rate, Yield response was observed for individual grass species with each additional 4-ton/A increment of litter. Greater responses were observed between the 0- and 4-ton/A rate for tall fescue (74.3%) and bermudagrass (69.0%) than for other species. Dry matter yields for eastern gamagrass indicated the lowest increase (31.4%) in production with the addition of 4-ton/A of litter.

Generally, the cool-season perennial species produced lower DM yields at the 0- and 4-ton/A rates than other species except for Old World bluestem. Yield increases between the 4- and 8-ton/A litter rates were less than half of the DM yield observed for increases between the 0- and 4-ton/A rates. The largest DM yield observed was for the annual rye, ryegrass, and forage sorghum combination for the three litter treatments. The warm-season annual contribution was 76.2,62.9, and 62.7% of the total production at 0-, 4-, and 8-ton/A litter rates, respectively.

Seasonal DM distribution indicates that the majority of production occurred by the middle of the growing season. Producers should consider limiting applications past the midpoint in the growing season to facilitate maximum uptake of N resulting from applied poultry litter.

Tissue N accumulation (Table 2) in grass species with 0-ton/A litter ranged from 38.9 to 165.3 lb/A N; from 173.1 to 450.7 lb/A N with 4-ton/A litter; and from 236.3 to 696.5 lb/A N with 8-ton/A of applied litter. Tissue N removed by grass species increased with each additional 4-ton/A litter application. Similar to forage DM yield, there were substantial differences in N accumulation between species and between litter rates. An interesting comparison between two warm-season perennials is the N accumulation for Old World bluestem (38.9 lb/A) and eastern gamagrass (115.4 lb/A) at the 0-ton/A rate of litter.

Changes in N removal between the 0- and 4-ton/A and 4- and 8-ton/A rates were more similar for tall fescue (75.1 and 61.4%, respectively) and orchardgrass (67.1 and 55.6%, respectively) than for other grass species evaluated. Percentage changes between the 0 and 4-ton/A rates for eastern gamagrass (42.7%), Old World bluestem (77.5%), and switchgrass (66.4%) were greater than for changes between the 4- and 8-ton/A rates for the same species (14.8,27.6, and 26.1%, respectively). The coollwarm-season annual combination removed substantially more litter applied N at all three application rates than other evaluated species. The annual combination of a cool/warm-season species removed 159 and 185.1 lb more N/A at the 4- and 8-ton/A rate, respectively, than the perennial bermudagrass species.

Laboratory analysis determined that one ton of poultry litter contained approximately 80 lb N. Depending on the grass species and the application rate, average recovery of N as a percent calculated on total N applied ranged from 54.1 to 140.6% for 4-ton/A and from 36.9% to 108.8% for 8-ton/A of applied litter. Generally, all grass species evaluated were more efficient at N recovery at the 4-ton/A than at the 8-ton/A application rate. Nitrogen utilization for orchardgrass was slightly greater at the 8-ton/A (60.9%) than for the 4-ton/A

Table 1. Seasonal *dry* matter yields of grass species as influenced by 0-, 4-, and 8-tons/acre of applied poultry litter.

	Litter application rate (tons)		
Species	0	4	8
		lb/A	
Coollwarm-season annual	10,765.3	22,932.3	26,903.9
Bermudagrass	4,004.7	12,936.6	18,524.7
Tall fescue	2,109.7	8,213.9	11,187.4
Eastern gamagrass	6,048.9	8,818.1	10,077.6
Old World bluestem	1,660.0	4,840.8	7,387.0
Orchardgrass	2,370.0	6,906.8	11,906.6
Reed canarygrass	3,531.3	7,644.1	11,557.3
Switchgrass	4.735.2	11.268.7	13.704.5

Table 2. Seasonal nitrogen removal by grass species fertilized with variable rates of poultry litter.

	Litter application rate (tons)		
Species	0	4	8
		lb/A	
Coollwarm-season annual	165.3	450.7	696.5
Bermudagrass	60.9	291.7	511.4
Tall fescue	48.8	193.5	360.9
Eastern gamagrass	115.4	201.9	236.3
Old World bluestem	38.9	173.6	239.6
Orchardgrass	57.4	173.1	390.8
Reed canarygrass	91.1	232.9	405.4
Switchgrass	78.7	232.8	314.3

(54.1%) litter rate. Similar to orchardgrass, Old World bluestem at the 4-ton/A rate was the least efficient (54.1%) at N recovery. Eastern gamagrass and Old World bluestem N recovery values at the 8-ton/A litter rate averaged 36.9 and 37.3%, respectively, which were the lowest values recorded for all species.

At the 4-ton/A rate, the cool/warm-season annual (140.6%) and bermudagrass (90.9%) were more efficient than other species in N recovery and were 108.8 and 79.8%, respectively, effective in litter applied N recovery at the 8-ton/A rate.

Nitrate-N concentrations in soil water under study plots receiving zero poultry litter resulted in mean NO_3-N concentrations that were generally lower than for the 4- and 8-ton/A application rates (Table 3). Mean NO_3-N soil water concentrations at the 18-inch depth were usually lower in May 1994 than in December of the same year. Mean values recorded for June 1993 were baseline means prior to the application of poultry litter at the 4- and 8-tonlA rates. Higher mean NO_3-N concentrations were detected in soil water collected with the addition of poultry litter at the 4- and 8-ton/A application rates.

Table 3. Effect of variable poultry litter rates applied to various grass species on soil moisture $N0_3$-N concentrations (ppm).

Species	June 1993	May PN4	December 1994
		0 Tons/acre	
Cool/warm-season annual	33.05	0.45	1.18
Bermudagrass	8.84	0.50	0.83
Tall fescue	15.39	0.35	2.75
Eastern gamagrass	50.31	1.27	0.66
Old World bluestem	4.10	5.23	0.49
Orchardgrass	21.54	1.47	4.12
Reed canarygrass	0.38	0.47	0.44
Switchgrass	3.01	0.27	0.52
Summer fallow	48.08	47.60	49.38
Fall fallow	42.39	50.20	55.15
		4 Tons/acre	
Cool/warm-season annual	28.14	1.30	3.01
Bermudagrass	6.80	0.20	0.53
Tall fescue	7.75	1.70	0.36
Eastern gamagrass	57.53	10.00	18.69
Old World bluestem	10.16	2.17	7.69
Orchardgrass	2.57	0.20	1.55
Reed canarygrass	1.95	0.47	0.33
Switchgrass	2.03	3.60	1.64
Summer fallow	39.66	37.90	48.37
Fall fallow	43.91	45.10	68.77
		8 Tons/acre	
Cool/warm-season annual	41.98	5.10	10.85
Bermudagrass	10.20	17.80	51.76
Tall fescue	36.04	1.92	9.37
Eastern gamagrass	39.30	20.52	112.86
Old World bluestem	13.92	19.92	39.27
Orchardgrass	15.90	5.47	16.21
Switchgrass	3.54	5.63	46.98
Reed canarygrass	1.67	0.83	4.51
Summer fallow	61.38	40.91	92.27
Fall fallow	42.99	24.50	81.68

The water samplers did not collect soil water from May until November because of high transportation rates and low precipitation during that period. The lower $N0_3$-N concentrations recorded for May 1994 possibly were affected by various factors such as grass species growth rate when plants are more active in nutrient utilization during a period of high evapotranspiration and lower precipitation, resulting in lower soil moisture content.

Mean NO,-N concentrations for December 1994, indicated the possibility for greater potential of NO_3-N leaching than during the summer months. Increased NO_3-N leaching occurring mostly during the late fall and early spring periods in the north central or northeastern United States when evapotranspiration is low has been reported by Chichester (1977) and Daliparthy et al. (1994).

Conclusions

Application of poultry litter at the 4- and 8-ton/A rates increased dry matter production, N accumulation in plant tissue, and NO_3-N concentrations in soil water. Differences in DM production were more pronounced between 0- and 4-ton/A than mean differences observed between the 4- and 8-ton/A application rates. The cool/warm-season annual combination of rye and ryegrass and forage sorghum produced more DM at the 4-ton/A (9,996 lb/A) and 8-ton/A (8,379 lb/A) than the next highest producing grass species, bermudagrass.

Nitrogen accumulation efficiency on a percentage basis of total N applied indicated that the cool/warm-season annual combination and bermudagrass were more effective at N uptake than other species. Nitrate-N soil water concentrations were lower in May than December 1994. Increased plant growth and evapotranspiration may have contributed to these observations.

Literature Cited

Chichester, F.W. 1977. Effects of increased fertilized rates on nitrogen content of runoff and percolate from monolith lysimeters. J. Environ. Qual. 6:211-217

Daliparthy, J., S.J. Herbert, and P.L.M. Veneman. 1994. Dairy manure applications to alfalfa: crop response, soil nitrate, and nitrate in soil water. Agron. J.86:927-933.

Giddens, J., and A.P. Barnett. 1980. Soil loss and microbiological quality of runoff from land treated poultry litter. J. Environ. Qual. 9:518-520.

Hileman, L.H. 1973. Response of orchardgrass to broiler litter and commercial fertilizer. Rep. Ser. 207, Arkansas Agricultural Experiment Station, University of Arkansas, Fayetteville, AR.

Huneycutt, H.G., C.P. West, and J.M. Phillips. 1988. Responses of bermudagrass, tall fescue and tall fescue-clover to broiler litter and commercial fertilizer. Bull. 913, Arkansas Agricultural Experiment Station, University of Arkansas, Fayetteville, AR.

Khaleel R., K.R. Reddy, and M.R. Overcash. 1980. Transport of potential pollutants in runoff water from land areas receiving animal wastes: a review. Water Research 14:421-436.

Liebhardt, W.C., C. Golt, and J. Turpin. 1979. Nitrate and ammonium concentrations of ground water resulting from poultry manure applications. J. Environ. Qual. 8:212-215.

Loehr, R.C. 1970. Animal waste management—problems and guidelines for solutions. Presented at the Symp. on Agriculture and the Quality of the Environment of the Seventies, Chicago, IL. American Association for the Advancement of Science, Washington, DC.

Lorimar J.C., L.N. Mielke, L.F. Elliot, and J.R. Ellis. 1972. Nitrate concentrations in ground water beneath a beef cattle feedlot. Water Resources Bull. 8:999-1005.

McLeod, R.V., and R.O. Hegg. 1984. Pasture runoff water quality from application of inorganic and organic nitrogen sources. J. Environ. Qual. 13:122-126.

Sommerfeldt T.G., U.J. Pittman, and R.A. Milne. 1973. Effect of feedlot manure on soil and water quality. J. Environ. Qual. 2:423-427.

Stewart, B.A. 1980. Utilization of animal manures on land: state-of-the-art. *In* Livestock Waste: Renewable Resource. Proc. 4th Int. Symp. on Livestock Wastes. ASAE, St. Joseph, MI. pp. 147-9, 155.

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Winter Cover Crops' Influence on Cotton Yield

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Introduction

Winter cover crops, usually legumes, may have had a useful role in cotton *(Gossypium hirsutum* L.) production in the Midsouth until about 1950 (Keisling et al., 1994). Cover crops were primarily used to provide nitrogen to the subsequent cotton crop. They also provided the benefit of increased humus (organic matter) in the soil. Humus is the key component for maintaining high quality soil. It builds soil structure and tilth (Reicosky and Lindstrom, 1993). Excessive tillage greatly accelerates the breakdown of organic matter (Keisling et al., 1994).

Winter cover crops, while beneficial, also have associated costs. Costs of seed, planting, elimination by shredding or herbicides, and the shortened spring season for seedbed preparation must be weighed against measurable or potential benefits. From the mid-1900's through the present, Midsouth cotton producers have opted for commercial nitrogen fertilization rather than the green manure crops.

The size of farm machinery has increased dramatically since the 1960's. With these larger machines comes a change in seedbed preparation, from flat breaking to running a disk harrow as a primary tillage tool (Reicosky and Lindstrom, 1993). Humus depletion has been shown to increase as the number of tillage trips increase. Cotton producers may make as many as 10 or `trips per acre in preparing the seedbed (Keisling et al., 1995).

The organic matter of many of the more productive Midsouth soils is approximately one percent. As organic matter decreases, soil tilth is lessened and compaction problems rob producers of profits. The traffic pan reduces root penetration and water infiltration. To combat this, many producers are using subsoilers to break this traffic pan. These trips require high horsepower, have a high cost per acre, take valuable time during fall or spring seedbed preparation, and results are unpredictable (Keisling et al., 1995).

Planting a green manure cover crop has been shown in studies to have a positive impact on yields (Keisling et al., 1994). Cover crops offer advantages other than yield increases. In the winter and early spring, when heavy rainfall is more likely, an established cover can slow water runoff, thereby, keeping soil in place and possibly avoiding fertilizer or herbicide contamination in streams or underground aquifers.

The practical significance of humus loss or 'burn-out' can be summarized as (1) mineralization of soil organic nitrogen for subsequent uptake and use for plant growth, (2) deterioration of soil tilth and soil structure with increased surface crusting, an d (3) less amelioration and degradation of some herbicides (Keisling et al., 1994). A concern about the adverse impact of continuing organic matter loss led to the establishment of this experiment.

Materials and Methods

In 1994, research was done at the Delta Branch Station, Clarkedale, AR on a Dubbs (fine silty, mixed, nonacid, t mic Typic HapludalQ-Dundee (fine silty, mixed, thermic Aeric Ochraqualf) soil association. 'Deltapine 51' cotton was planted on May 17. Seeds were double-treated and planted at a seeding rate of eight seeds per row/foot. The cover crop treatments were originally established in a randomized complete block design. The test has been modified to some degree as to cover crops, herbicides, and seedbed preparation used (Keisling et al., 1994). Currently, the experimental design consists of cover crop main plots arranged in a randomized complete block. Main plots are split for tillage comparisons of ridge-till versus conventional tillage. The cover crops are listed in Table 1. Cotton management practices are summarized in Table 2.

In-season management practices for 1994 are as follows. Herbicides were varied according to the type of treatment imposed. The conventionally tilled cotton received a broadcast rate of 1 lb ai/A of trifluralin on April 27, incorporated to a depth of 1.5 inches. Fluometuron at 0.8 lb ai/A was banded behind the planter on May 17. The minimum-tilled cotton received 0.63 lb ailA of paraquat on April 18 and received an application of metolachlor at 1.5 Ib ai/A on April 27. The ridge-tilled treatments received two post-directed applications (June 13 and June 16) of fluometuron 0.6 lb ai/A and MSMA at 1.1 lb ai/A. On June 16, the minimum-tilled plots received a post-directed application of fluometuron 0.6 lb ailA and MSMA at 1.1 lb ai/A.

Also, conventional plots were mechanically cultivated with a Buffalo@ cultivator on June 1, June 6, June 15, and June 28. The Buffalo cultivator was used in the minimum-tilled plot on June 15 and June 28. All plots in 1994 were flame-cultivated on July 6, July 14, and July 21. Propane was set at 30 PSI and travel speed was 3 MPH.

Insecticide applications were the same for all plots. Azin-

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phosmethyl was applied at the broadcast rate of 0.25 lb aiIA on June 15 and June 20 for the control of boll weevil. Cyfluthrin and profenofos were applied at the rate of 0.04 lb ai/A and 0.25 lb ai/A, respectively, on August 9, August 16, and August 30 €or worm and egg control.

Four 40-inch-wide rows were planted in each plot and trimmed back to harvest length of 50 feet. Mean harvest plant population for all plots was 44,981 plants per acre. The field was limed according to soil tests at the rate of 2.5 tons/A on March 20, 1994. Nitrogen was applied at the rate of 90 lb/A as ammonium nitrate on June 1, followed by a sidedress application of 30 lb N/A of 32% solution on June 17. Foliar applications were made on August 8 and August 12 of 4.6 !h/A as urea and 0.1 1bIA boron each trip. These plots received no supplemental irrigation, but 18.2 inches of rainfall were recorded from May through October.

Harvest aids, consisting of tributul phosphorotrithioate at 0.75 lb ai/A, glyphosate at 0.8 Ib ai/A, and ethepon at 1.5 lb ai/A, were applied on September 13. Cotton was machine-harvested first on Oct. 4, 1994 and picked the second time on Oct. 11, 1994. Gin turnout was based on returns of station-picked cotton processed at a local gin.

Results and Discussion

The statistical analysis for yield indicated no interactions. The wheat and clover cover crops in 1994 yielded significantly higher than wheat and vetch alone as shown in Table 1. Table 1 also points out the combination of wheat with a legume resulted in higher yields than the legume alone. The reason for this is possibly because while the legume fixes N, the wheat acts like a scavenger and in its uptake produces more plant mass that better facilitates the following cotton crop. The yield difference between conventional tillage and ridge-tillage was not significant, Table 1. This could be due in part to the good 1994 crop year, but more particularly to the cultivation performed on the test after emergence.

The results of soil mineral analysis are given in Table 3. The organic matter of conventional and ridge-till were essentially equal. Stratification of soil pH, organic matter, K, Ca, Na, Mg, Fe, P, NO;, and EC is apparent. It is interesting to note that Na, an element taken up only in small amounts by plants, is being lessened in the surface soil layer (0 to **2** inches). All other soil characters are being increased. The cover crop influenced soil pH, Cu, NO;, and EC. Essentially, the pure legume had higher NO; and lower pH, while the legume-grass mixture was intermediate in NO;. The EC basically reflected the soil NO; content. Tillage systems only influenced soil P levels, with ridge-till having measurably more P than conventional.

Table 1. Yield of lint cotton at the Delta Branch Experiment Station, 1994.

Cover	Yield (1b/A)
Wheat and Clover	1,130.94 a*
Wheat and Vetch	1,060.59 b
Winter Weeds	973.69 c
Vetch	968.02 c
Tillage	
Conventional	1,046.92 a
Ridge-till	1.007.63 a

*Numbers in the same column and category followed with the same letter are not significantly different at the ***5%*** level.

Table 2. Summary of the cotton management practices by year.

	Date of Planting		Fertilizer			Harvest	Cotton
Year	**Cover**	**Cotton**	**Amount**	**Type**	**Time**	**Dates**	**Cultivar**
			(Kg/ha)				
1994	10-10-93	5-17-94	100	NH4NO,	sd*	10-4-94	DPL 51
			34	NH4N03	sd	10-11-94	
			10	urea	sd		

* sidedressed

Literature Cited

Keisling, T.C., R.F. Ford, and H.D. Scott. 1995. Tillage Systems for Cotton on Mississippi River Delta and Loessial Plains Soils. Commun. Soil Sci. Plant Anal., 26:3-4, 441-452.

Keisling, T.C., H.D. Scott, B.A. Waddle, W. Williams, and R.E. Frans. 1994. Winter Cover Crops Influence on Cotton Yield and Selected Soil Properties. Commun. Soil Sci. Plant Anal., 25:19-20, 3087-3100.

Reicosky, D.C., and M.J. Lindstrom. 1993. Fall Tillage Methods: Effect on Short Term Carbon Dioxide Flux from Soil. Agron. Journal. 8511237-1243.

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Table 3. Soil Test1 Results for Various Tillage, Cover Crops, and Depths in the Fall of 1994.

	Soil Test Results													
	PH	O.M.~	K	Ca	Na	Mg	Fe	Mn	Cu	Zn	S	P	NO3	EC
Depth		(%)	lb/A											(moh)
0 to 2 in.	6.0a*	1.4a	392a	2185a	134b	461a	336b	60a	2.6a	7.4a	51a	158a	89a	137a
2 to 6 in.	5.4b	1.2b	287b	1980b	142a	358b	351a	60a	2.6a	7.2a	48a	125b	79b	122b
Level of Sig.	1%	1%	1%	1%	5%	1%	1%	10%	10%	10%	10%	1%	1%	1%
Cover2														
Vetch	5.5b	1.2a	317a	2038a	136a	393a	348a	60a	2.7ab	7.1a	48a	139a	96a	139a
Wheat & Clover	5.5b	1.3a	330a	2035a	144a	395a	357a	64a	2.4b	7.2a	4 6a	138a	Slab	124b
Wheat & Vetch	5.5b	1.3a	327a	1904a	130a	374a	347a	57a	2.4b	7.4a	51a	133a	Slab	127ab
Winter Weeds	5.8a	1.2a	316a	2190a	147a	404a	336a	60a	2.8a	7.3a	50a	134a	74b	120b
Level of Sig.	5%	10%	10%	10%	10%	10%	10%	10%	5%	10%	10%	10%	10%	5%
Tillage*														
Ridge-till	5.6a	1.2a	328a	2107a	140a	400a	344a	61a	2.7a	7.4a	49a	140a	84a	130a
Conventional	5.6a	1.2a	316b	1992b	139a	384b	348a	59a	2.5b	7.1a	49a	132b	81a	125a
Level of Sig.	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	5%	10%	10%

¹ Soil test results were obtained using 1994 University of Arkansas soil testing procedures.
* Means are weighted according to depth of the sample to give 0 to 6 inches or an acre furrow slice.
³ O.M. = Organic Matter.
* Numbers in the same column and category followed with the same letter are not significantly different.

Profitability of Seven Nonirrigated Soybean Cropping Rotations on a Shallow Silt Loam Soil

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Introduction

Crop rotation has been recognized for quite some time as a good way to control soilborne diseases. With the removal of Dibromochloropropane, the most cost-effective nematacide for general use in soybean *(Glycine max* L.) production, about the only control left for the cyst nematode *(Heteroderu Glycine* Ichinohe) is selection of resistant soybean cultivars coupled with crop rotation. Previous work has indicated that nonhost crops for one year in rotation dramatically decreased the nematode population (Riggs, 1995, Personal Comm.). In the Mississippi Delta and loessial terraces regions of Arkansas, there are several million acres of loess-derived soils that are quite low in organic matter and very prone to having severe cyst nematode problems. Cropping patterns of the region on nonirrigated land not cropped to cotton are almost exclusively continuous soybeans or doublecropped wheat-soybeans. The wheat residue is burned on almost the entire acreage planted to wheat. This straw burning has been perceived by agronomists as a bad practice on soils with very low organic matter (< 0.8 %) for as long as it has been occurring. Agronomically feasible crop rotations that result in nematode suppression were studied. These crop rotations were compared to ones currently utilized in continuous soybeans and doublecropped wheat-soybeans. The practice of leaving the wheat residue and no-till crop production were investigated.

Materials and Methods

Agronomic

The study reported herein was conducted from 1980 to 1984 at the Arkansas Cotton Branch Experiment Station on a Loring-Calloway-Henry (Alfisol) silt loam. The soil test values were 6.2 for soil pH with 0.6% organic matter and 64 and 170 pounds per acre P and K, respectively. The study included seven rotational cropping systems composed of continuous soybeans (monocropped), wheat-soybeans doublecropped, and five biennial rotations of which two are single crops per year and the others doublecrop systems. The cropping sequences are shown in Table 1. Additional cultural practices were imposed on selected crop rotations. The continuous soybeans and wheat-soybean doublecrop systems were grown both conventionally and no-till. The wheat-soybean doublecrop also had residue management treatments; the wheat stover was either burned or left. This resulted in a total of four doublecropped wheat-soybean production systems and two continuous soybean systems.

A total of 11 crop production systems were arranged in a randomized complete block design with three replications. Individual production system plots were 13.7 feet x 100 feet. Grain sorghum and soybeans were planted on 38-inch rows with a conventional planter (John Deere 7100) equipped for no-till by using cutting coulters, double disk openers, cast iron press wheels, and heavy down pressure springs, while the wheat was sown in 7.5-inch rows with a Crust Buster@ no-till drill. Wheat residue was burned in all cases where the crop production system did not specify that it was to remain.

The study area was planted to soybeans in the summer of 1980. The study began with wheat planted that fall and summer crops in the spring of 1981. Yields were determined by harvesting the two center rows in each plot for grain sorghum and soybeans or a 60-inch wide swath in the center of the wheat plots. Grain yields were adjusted to 14.0, 13.0, and 13.0% moisture for grain sorghum, soybeans, and wheat, respectively.

Soybeans monocropped. Conventional 'Forrest' soybeans were planted at 180,000 seeds per acre between June 1 and June 15. Preemergence herbicides consisted of metribuzin at 0.375 lb ai/A and alachlor at 2.5 lb ai/A. Seedbed preparation consisted of disking once and going over with a do-all. Mechanical cultivations were done at V3 stage once each year. Harvest dates ranged from October 18 to October 28. No-till production consisted of a chemical burndown with paraquat at 0.468 lb ai/A per acre at planting. Preemergence herbicides consisted of metribuzin at 0.375 lb ai/A and alachlor at 2.5 lb ai/A. Postemergence herbicides used were sethoxydin at 0.187 lb ai/A per acre and an oil-based surfactant. Otherwise, production practices were the same as conventional.

Soybeans doublecropped. Conventional 'Forrest' soybeans were planted at 180,000 seeds per acre between June 1 and June 15. Wheat residue was either burned or left according to the production system. The seedbed was prepared by disking once and going over with a do-all. The preemergence herbicides used were trifluralin at 0.75 lb ai/A and metribuzin at 0.375 lb ai/A. One or two mechanical cultivations were

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Table 1. Cropping sequences and seedbed preparation for 11 crop production systems from 1981 to 1984.

			Year							
		Wheat	1980	1981	1981	1982	1982	1983	1983	1984
Crop Rotation	Tillage	Stubble	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
GS , S	Conv.	—	—	GS	—	S	—	GS	—	S
S , S	Conv.	—	—	S	—	S	—	S	—	S
	No-till	—	—	S	—	S	—	S	—	S
W - F , S	Conv.	Bum	W	—	—	S	W	—	—	S
W - G S , S	Conv.	Bum	W	GS	—	S	W	GS	—	S
W - G S , W - S	No-till	Burn	W	GS	W	S	W	GS	W	S
W - S , S	Conv.	Bum	W	S	—	S	W	S	—	S
W - S , W - S	Conv.	Bum	W	S	W	S	W	S	W	S
	No-Till	Burn	W	S	W	S	W	S	W	S
	Conv.	Leave	W	S	W	S	W	S	W	S
	No-till	Leave	W	S	W	S	W	S	W	S

[1] Yearly cropping rotations are divided by comma (,) and individual crops harvested same year are divided by hyphen (-).
[2] Crops are shown as 'GS' for grain sorghum, 'S' for soybean, 'W' for wheat, and 'F' for fallow.

done between June 8 and June 18. Harvest dates ranged from October 18 to October 28. No-till production began with burning or leaving the wheat residue as the production system required. Those with wheat residue remaining received a burndown of paraquat at 0.468 lb ai/A just prior to planting. Post-plant weed control was accomplished by sethoxydim at 0.187 lb ai/A and an oil-based surfactant. Other cultural practices were the same as the conventional production system.

Grain sorghum monocropped. Conventional 'Funk's G522DR' grain sorghum was planted at a seeding rate of 90,000 seeds per acre between June 8 and June 1 5 Seedbed preparation consisted of disking, bedding, and going over with a do-all. The post-emergence herbicide applied was atrazine at 2 lb ai/A. Mechanical cultivations were done at the six-leaf growth stage (Vanderlip and Reeves, 1972). Urea was applied broadcast over the area at the rate of 100 lb N/A to supply nitrogen requirements. Harvest ranged from October 20 to October 29.

Grain sorghum doublecropped. The agronomic inputs that changed from monocropped conventionally grown grain sorghum follow. Grain sorghum was planted between June 18 and June 20. Urea was applied broadcast in early spring at the rate of 60 lb N/A. No-till production differed from conventional in that a chemical burndown of atrazine at 2 lb ai/A was used instead of mechanical seedbed preparation.

Wheat. 'Oasis' soft red winter wheat was drilled at a seeding rate of 1,350,000 seeds per acre between October 29 and November 5. Seedbed preparation for conventional plots consisted of disking and going over with a do-all. Both conventional and no-till plots were planted using a Crust Buster no-till drill. Harvest dates ranged from June 1 and June 14.

Economic Analysis

Budgets were compiled on each cropping system annually by using the Mississippi State Budget Generator computer program (Spurlock, 1992). Crop prices were based on 6-year averages (1986-1993) for each crop. Total income was calculated by multiplying yield and average crop price. Direct expenses were calculated by using average costs paid for seed, chemicals, and fuel. Fixed expenses were calculated based on prices paid for using equipment such as tractors, combines, and other field equipment. Total expenses included both direct and fixed expenses combined. Net returns are considered the difference between total income and total expenses. Average net returns are calculated based on all 4 years' data combined. Gross income, total expenses, and net returns for the doublecrop rotations include the total income, expenses, and returns for both crops produced in each system. No charge was issued for land, overhead labor, other overhead, crop insurance, real estate taxes, and management.

Results and Discussion

Grain yields for the study are shown in Table 2. These particular crop rotations were selected for the alternation of host crop for soilborne plant pathogens, weed spectrum easily controlled by available herbicides, and economic potential. Other production practices were included to reduce mechanical inputs (no-till) or to retain crop residue. Wheat yields in the study were significantly lower in those cropping systems where wheat followed grain sorghum or in those systems where the wheat residue was left on the surface. The grain sorghum yields were significantly different in each production system employed. Grain sorghum yields were highest in the monocrop grain sorghum-monocrop soybean rotation. Grain sorghum yields were the lowest under the total doublecropped wheat-grain sorghum-monocrop soybean rotation. The difference in the monocropped grain sorghum versus doublecropped grain sorghum was expected. However, the different grain sorghum yield for the two doublecropped systems was not expected. The no-till doublecropped grain sorghum yielded measurably less than the conventional doublecropped grain sorghum.

The soybean yields showed more complex results than did

Table 2. Grain yield for the 11 cropping systems.

Crop Rotation[1,2]	Tillage	Wheat Stubble	Crop	1981	1982	1983	1984	Avg.
				bu/acre				
GS , S	Conv.	—	GS	86.0[3]	—	107.1	—	96.6
	Conv.	—	S	—	40.8	—	36.8	38.8
S , S	Conv.	—	S	28.7	31.2	17.1	35.4	28.1
	No-Till	—	S	34.6	20.2	10.7	31.2	24.2
W - F , S	Conv.	Burn	W	34.0	—	38.6	—	36.3
	Conv.	Bum	S	—	34.7	—	34.6	34.6
W - G S , S	Conv.	Bum	W	34.0	—	40.6	—	37.3
	Conv.	Burn	GS	62.3	—	62.3	—	62.3
	Conv.	Burn	S	—	36.7	—	36.9	36.8
W - GS , W - S	No-Till	Bum	W	34.0	28.0	40.1	32.3	33.6
	No-Till	Burn	GS	36.0	—	35.5	—	35.8
	No-Till	Burn	S	—	28.7	—	33.9	31.3
W - S , S	Conv.	Burn	W	34.0	—	40.1	—	37.1
	Conv.	Bum	S	27.1	32.7	16.4	39.0	28.8
w - s , w - s	Conv.	Bum	W	34.0	34.7	37.6	42.1	37.1
	Conv.	Bum	S	34.6	30.3	19.4	33.9	29.5
	No-Till	Burn	W	34.0	32.0	38.6	43.9	37.1
	No-Till	Burn	S	35.3	31.2	19.0	35.4	30.2
	Conv.	Leave	W	34.0	31.4	35.7	34.1	33.8
	Conv.	Leave	S	33.1	31.0	16.8	36.5	29.4
	No-Till	Leave	W	34.0	34.0	37.1	23.7	32.2
	No-Till	Leave	S	39.5	29.4	19.0	26.6	28.6

¹ Yearly cropping rotations are divided by comma (,) and individual crops harvested same year are divided by hayphen (-).
² Crops are shown as 'GS' for grain sorghum, 'S' for soybean, 'W' for wheat, and 'F' for fallow.
³ Measured plots yields of 16 bu/acre were adjusted to 86 bu/acre based on experiment station average on 300 acres. Small plots of early grain sorghum were heavily damaged by birds.

Table 3. Total income (TINC), total expenses (TEXP), and total returns above expenses (TRET) for the 11 crop systems.

Crop Rotation	Tillage	Wheat Stubble	1981 TINC	1981 TEXP	1981 TRET	1982 TINC	1982 TEXP	1982 TRET	1983 TINC	1983 TEXP	1983 TRET	1984 TINC	1984 TEXP	1984 TRET
			$/acre											
GS , S	Conv.	—	175.44	120.32	55.12[3]	245.82	134.70	111.12	218.55	123.56	94.99	221.55	134.08	87.46
S , S	Conv.	—	172.98	75.00	97.98	188.03	133.23	54.80	102.94	73.21	29.73	213.11	134.87	78.24
	No-till	—	208.29	76.85	131.44	121.61	116.61	5.00	64.41	76.42	(12.00)	187.53	118.28	69.25
W - F , S	Conv.	Burn	108.46	70.78	37.68	208.69	133.75	74.94	123.13	71.50	51.63	208.29	133.74	74.55
W - G S , S	Conv.	Bum	235.62	170.51	65.11	221.13	134.06	87.07	256.67	171.54	85.13	222.14	134.10	88.04
W - GS , W - S	No-till	Bum	181.83	141.15	40.68	262.29	158.92	103.37	200.41	142.04	58.37	307.01	154.11	152.90
w - s , s	Conv.	Bum	271.80	139.31	132.49	196.86	133.46	63.40	226.65	138.64	88.01	234.58	134.41	100.17
W - S , W - S	Conv.	Bum	316.55	140.40	176.15	292.90	145.74	147.16	236.84	138.66	98.18	338.28	147.46	190.82
	No-till	Burn	320.76	147.28	173.48	289.70	157.86	131.84	237.72	145.53	92.19	353.35	160.38	192.97
	Conv.	Leave	307.72	139.78	167.94	287.09	148.98	138.11	214.92	137.55	77.37	328.61	150.24	178.37
	No-till	Leave	346.05	158.88	187.17	285.35	159.97	125.38	232.82	156.26	76.56	235.54	157.93	77.61

1 Yearly cropping rotations are divided by comma (,) and individual crops harvested same year are divided by hyphen (-).
* Crops are shown as 'GS' for grain sorghum, 'S' for soybean, 'W' for wheat, and 'F' for fallow.
³ No charge was issued for land, overhead labor, other overhead, crop insurance, real estate taxes, and management.

Table 4. Total income (TINC), total expenses (TEXP), and total returns above expenses (TRET) for the 11 crop systems averaged over 4 years.

Crop Rotation	Tillage	Wheat Stubble	Average of 1981 through 1984 TINC	TEXP	TRET
				$/acre	
GS , S	Conv.		215.34	128.17	87.17[3]
S , S	Conv.		169.26	104.07	65.19
	No-till		145.46	97.04	48.42
w - F , S	Conv.	Burn	162.15	102.45	59.70
w - G S , S	Conv.	Bum	233.89	152.55	81.34
W - *GS* , W - S	No-till	Bum	237.89	149.06	88.83
W - S , S	Conv.	Burn	232.47	136.45	96.02
W - S , W - S	Conv.	Burn	296.14	143.06	153.08
	No-till	Burn	300.38	152.76	147.62
	Conv.	Leave	284.59	144.14	140.45
	No-till	Leave	274.94	158.26	116.68

[1] Yearly cropping rotations are divided by comma (,) and individual crops harvested same year are divided by hyphen (-).
[2] Crops are shown as 'GS' for grain sorghum, 'S' for soybean, 'W' for wheat, and 'F' for fallow.
[3] No charge was issued for land, overhead labor, other overhead, crop insurance, real estate taxes, and management.

the grain sorghum or wheat. The continuous monocropped soybeans yielded significantly less (approximately 10 bu/A) than any monocropped soybeans following a full year of a crop that is a nonhost for cyst nematode. In fact, the monocropped continuous soybeans had yields equivalent to doublecropped soybeans. The yield of doublecropped soybeans following a full year of nonhost was not any better than those where soybeans were included in the prior year. This indicates that the "rotational effect" of the year of nonhosts did not extend to doublecropped soybeans. Over the entire 4 years of the study, average net returns ranged from a high of $153.08 for conventionally produced doublecropped wheat-soybeans to a low of $57.64 (Table 3 and 4) for no-till continuous soybeans. Of the crop rotation systems, the wheat-soybeans continuous doublecropped systems, regardless of tillage practice and stubble management, produced the largest net returns. The least favorable of these four was for soybeans was no-tilled into wheat residue. At the time of this study, the technology was not available to make this treatment yield as it should (Keisling et al, 1994). Therefore, the net profits reported for continuous doublecropped wheat-soybeans with wheat residue left and soybeans no-tilled into the wheat straw will be lower than can be currently expected. The next most profitable systems were monocropped grain sorghum-soybeans, continuous doublecropped wheat-grain sorghum-wheat-soybeans and doublecropped wheat-soybeans-monocropped soybeans. These crops were about two-thirds as profitable as the profit maximizing system. The least profitable group was continuous soybeans regardless of tillage practice, wheat-summer fallow-monocropped soybeans, and doublecropped wheat-grain sorghum-monocropped soybeans. This least profitable group had about one-third the profits of the most profitable group.

Literature Cited

Keisling, T.C. et *al.* 1994. Differential soybean varietal response to no-till planting in wheat straw. Southern Conservation Tillage Conference for Sustainable Agriculture annual meeting. Columbus, S.C. *In* **P.J.** Bauer and **W.J.** Bassclier (eds.). Proceedings of the 1994 Southern Conservation Tillage Conference for Sustainable Agriculture. p. 89-94.

Spurlock, S.R. 1992. Mississippi State University Budget Generator. Miss. St. Univ. Ag. Econ. Tech. Publ. No. 88.

Vanderlip, R.L., and H.E. Reeves. 1972. **Growth** Stages of Sorghum. Agron. Journal. ***64:*** 13-16.

No-Tillage Field Corn and Vegetables Using Yard Waste Compost

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Abstract

Disposal of yard waste on farmland could help reduce the need for additional landfill disposal sites and should help improve soil quality and productivity. The objective of this study was to determine the effect of disposal of yard waste compost (YWC) on production of field corn (Zea *mays*) and vegetables. Several on-farm and experiment station studies were conducted from 1993 to 1994. Corn forage yield improved from the cumulative application of YWC. By the third year, YWC mulch-treated corn forage yields were 11.2 Mg/ha greater than control treatments, a highly significant economic difference. Much of the yield advantage from YWC application was attributed to improved soil water storage at corn planting time. Squash ***(Cucurbita pepo)*** and okra ***(Hibiscus esculentus)*** yields between locations were heavily dependent upon our ability to provide timely irrigation and the degree of nematode infestation. Transplanted seedlings and incorporated YWC treatments appeared to result in best yields, based upon our limited data.

Introduction

Interest in composting today is driven by the high cost of establishing and operating landfills as well as by new restrictions to reduce the amount of materials going into landfills, concerns over groundwater pollution by landfills, and generally a greater commitmenton the part of the public to recycling. Yard waste compost (YWC) is produced from plant-derived organic matter mostly from urban homeowners. New Jersey research (Kluchiniski, et al., 1993) confirmed our work in Florida (Gallaher and McSorley, 1994a; 1994b) because they reported that soil water and crop yields were increased and nematodes were generally decreased from use of leaf mulching as a soil amendment. In a no-tillage study, the senior author (Gallaher, 1977) found that no-tillage mulch planting management (killed rye *(Secale cereale* L.) cover crop) for corn *(Zea mays* L.) and soybean *(Glycine max* L. Merr.) resulted in more water conservation and drought tolerance for the crops. The no-tillage rye mulch treatments resulted in 46% and 30% greater corn and soybean seed yield, respectively, compared to control no-tillage plots where rye tops were removed for forage.

The Florida laws that have restricted disposal of organic yard trash in landfills (Kidder, 1993) have resulted in large reserves of YWC due to the building of composting facilities near urban areas. Experiment station and on-farm soil and crop management research will be required to overcome the fears of potential users (home gardeners and farmers), and to create markets for this YWC.

The objective of this study was to determine the effect of disposal of YWC on field corn and vegetable production.

Materials and Methods

Field corn forage experiments were in randomized complete block designs with five replications imposed on a farmer's field near Gainesville, FL from 1992 to 1994. Treatments for experiment one imposedon a Bonneaufine sand soil were: (Treatment 1) 0 Mg YWC/ha in 1992 + 269 Mg YWC/ha mulch (M) in 1993 + 269 Mg YWC/ha mulch in 1994; (Treatment 2) 0 Mg YWC/ha in 1992 + 269 Mg YWC/ha incorporated in 1993 + 269 Mg YWC/ha incorporated in 1994; (Treatment 3) 0 Mg YWC/ha all 3 years, the control treatment. Field corn experiments two and three differed from experiment one in that all treatments either received 134 Mg incorporated YWClha (experiment 2) or 269 Mg incorporated YWClha (experiment 3), respectively in 1992 only, followed by the same YWC applications used in experiment one for both 1993 and 1994.

Vegetable experiments were imposed on the same soil and treatment conditions at the farmer's location [squash *(Cucurbita pepo* L.); okra, *(Hibiscus esculentus* L.)] in 1993 and in 1993 and 1994 at the University of Florida Agronomy Farm. The soil on the Agronomy Farm was an Arredondo fine sand. The YWC used was identical to that used in the field corn experiments and the following similar treatments were imposed on each vegetable crop: 269 Mg/ha incorpo-

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rated, 269 Mg/ha M, and 0 Mgka(control). Less than 5 cm YWC was used in all cases except for < 2.5 cm YWC on vegetable plots in 1994. The YWC was analyzed for dry matter, organic matter, C, N, pH, and minerals using standard procedures. Yield data were taken from the middle two rows of the four- to six-row plots. Wood Resource Recovery of Gainesville, FL, donated, hauled, and assisted farmers and research assistants in spreading the YWC each year. The analyses of variance (ANOVA) of data were carried out using standard statistical procedures for randomized complete block and split-plot experimental designs.

Results and Discussion

The YWC was about 50% dry matter and had a very high C:N ratio (Table 1). Cumulative applications of YWC have totaled 806,672, and 269 Mg/ha for some treatments depending upon the experiment during the past **3** years (Table 2). The cumulative effects from large applications of YWC in our studies have resulted in significant increases in soil pH, extractable plant nutrients, CEC, and water holding capacity (data not shown). The YWC applications also resulted in significant, but sporadic decreases in populations of plant parasitic nematodes (particularly *Paratrichodorus minor* (Colbran) Siddiqi), depending on the experiment and year (Gallaher and McSorley, 1994a; other data not shown).

Increased forage yields of field corn from use of YWC ranged from 5.8 Mglha to 11.2 Mglha (based on 30% dry matter silage) depending upon the experiment (Table 2). Increased yield was positively correlated with the increased soil organic matter, improved soil fertility conditions, and greatly increased soil water storage capacity. At planting time for the third year of corn (1994), the top 0.64 m of soil, treated with YWC for a mulch, contained as much as 5.8 cm more water than the control without YWC. To replace this much water through irrigation would cost between $50 and $l00/ha depending upon the irrigation system used. Mulched YWC treatments consistently had greater amounts of stored soil water compared to the incorporated YWC treatments (Gallaher and McSorley, 1994b).

Squash yield was greater at the Green Acres Agronomy Farm than at the Haufler farm (Table 3). This was likely

Table 1. Analysis of yard waste compost used on the Haufler and Agronomy farm research experiments in 1992, 1993, and 1994.

Analysis	Company yard 1992A	Hauf. 1992A	Hauf. & Agron. 1993B	Hauf. 1994C	Agron. 1994D
DM g/kg	451.0	572.0	507.0	515.0	498.0
OM glkg	780.0	772.0	665.0	635.0	592.0
C g/kg	392.0	398.0	335.0	320.0	313.0
N g/kg	9.4	8.6	9.2	9.0	9.1
C:N ratio	41.7	46.3	36.4	35.6	34.4
pH chopped	6.2	**5**.7	—	6.5	7.5
pH ground	6.3	5.8	7.0	6.2	7.1
Ca g/kg	17.5	14.3	23.0	24.4	34.1
Mg g/kg	1.8	1.3	2.0	1.8	1.9
K g / k	2.6	1.9	3.2	2.8	2.9
p g/kg	1.2	0.8	1.9	1.5	1.8
Cu mg/kg	11.8	11.7	16.3	16.0	18.0
Fe mg/kg	1,448.0	1,580.0	1,473.0	1,793.0	1,825.0
Mn mg/kg	176.0	146.0	142.0	173.0	188.0
Zn mg/kg	151.0	91.**0**	112.0	96.0	118.0

DM = dry matter; OM = organic matter in DM; chopped = compost samples were chopped into coarse particles using a grinder; ground = subsamples of the chopped samples were ground with a Wiley mill to pass a 2 mm stainless steel screen. Values are the average of four replications.
A = < 5 cm size applied to the Haufler (Hauf.) **farm** field corn.
B = < 5 cm size applied to the Haufler field corn and vegetable experiments and the Agronomy (Agron.) farm vegetable experiment.
C = < 5 cvm size applied to the Haufman field corn.
D = < 2.5 cm size applied to the Agronomy **farm** vegetables.

Table 2. Compost treatment and field corn forage yield from use of yard waste compost (YWC) on Haufler farm research plots for 1992, 1993, and 1994.

Application Rates and Amount Applied				Forage Yield		
1992	**1993**	**1994**	**3-yr Total**	**1992**	**1993**	**1994**
Experiment number one						
Mg/ha				Mg/ha @ 30% DM		
0	269 M-IH	269 M-IH	538	28.0	23.1a	33.6a
0	269 I	269 I	538	28.0	21.3a	30.2ab
0	0	0	0	28.0	9.9 b	23.1 b
Experiment number two						
134 I	269 M-IH	269 M-IH	672	22.4	10.5a	27.1a
134 I	269 I	269 I	672	22.4	9.9a	23.3a
134I	0	0	134	22.4	9.4a	21.3a
Experiment number three						
269I	269 M-IH	269 M-IH	806	26.2	28.5a	41.0a
269 I	269 I	269 I	806	26.2	26.0a	38.5a
269 I	0	0	269	26.2	20.4b	29.8 b

M-IH = compost used as a mulch during the corn crop growing season and incorporated immediately after harvest each year.
I = compost incorporated 10 days before planting (DBP) in 1992, 40 DBP in 1993, and 110 DBP in 1994.
For yield data, values in columns not followed by the same letter are significantly different at the 0.05 level of probability.

Table 3. Cumulative total squash yield from application of 269 Mg/ha yard waste compost treatments.

Yard Waste Compost Treatment	Amount	Green Acres	Haufler Farm	Average
		Experiment Location, 1993		
	Mg/ha	kg/ha		
Conv. till incorporated	269	29,100	16,000	22,500a
No-till mulch	269	19,400	10,200	14,800b
Conv. till control	0	24,900	17,400	21,100a
Average		24,500	14,500*	

* Average values between experiment locations are. significantly different at the 0.10 level of probability. Average values among yard waste compost treatments not followed by the same letter are significantly different at the 0.05 level of probability.

because of better irrigation management on the Agronomy farm. No-tillage mulch compost gave a lower squash yield compared to conventional tillage incorporated squash (Table 3). Transplanted squash yield was 38% greater than yield of direct-seeded squash (Table 4). Insect damage to seedlings was a major problem.

Lower infestation of nematodes on the Haufler farm than on the Agronomy farm may be part of the reason for lower okra yield on the Agronomy farm (Table 5). Conventional tillage incorporated YWC resulted in the highest okra yield on the Haufler farm. Transplanted okra tended to give greater yield compared to directseeded particularly in the incorporated YWC (Table 6). Okra establishment was very difficult because of seedling death and insect damage. The heavy infestation of nematodes resulted in seedling death and stunted, low-producing plants. In general, vegetable yields were affected more by plant establishment methods than by YWC treatments, whereas YWC treatments were extremely beneficial for field corn.

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Literature Cited

Gallaher, R.N. 1977. Soil moisture conservation and yield of crops no-till planted in rye. Soil Sci. SOC.Am. J. 41:145-147.

Gallaher, R.N., and R. McSorley. 1994a. Management of yard waste compost for soil amendment and corn yield. pp. 156-160. *In* P.J. Bauer and W.J. Busscher (eds.) Proceedings of the 1994 Southern Conservation Tillage Conference for Sustainable Agriculture. Columbia, South Carolina, June 7-9, 1994. USDA-ARS Coastal Plains Soil, Water, and Plant Research Center, Florence, SC.

Gallaher, R.N., and R. McSorley. 1994b. Soil water conservation from management of yard waste compost in a farmer's corn field. Agron. Research Report AY-94-02, Agmn. Dept., Inst. Food and Agr. Sci., Univ. of Fla., Gainesville, FL.

Kidder, G. 1993. Applying non-hazardous wastes to land: I. Opportunities and problems. SS-SOS-43 Notes in Soil and Water Science, Univ. of Fla., Inst. Food and Agr. Sci. Coop. Extn. Serv., Gainesville, FL.

Kluchinski, D., J.R. Heckman, J. Mahar, D.A. Derr, and F. Kelly. 1993. Leaf Mulching: Using municipal leaf waste as a soil amendment. Special Report by the New Jersey Agr. Exp. Station, Rutgers Univ., Trenton, NJ.

Table 4. Cumulative total squash yield from application of 269 Mg/ha yard waste compost treatments, Green Acres, 1994.

Yard Waste Compost Treatment	Amount	Crop Establishment Method: Transplanted	Seeded	Average
	Mg/ha	kg/ha		
Conv. till incorporated	269	18,900	15,300	17,100
No-till mulch	269	14,800	9,800	12,300ab
Conventional till control	0	8,100	5,200	6,700 b
Averaee		13.900	10.100*	

*Average values between crop establishment methods are significantly different at the 0.05 level of probability. Average values among yard waste compost treatments not followed by the same letter are significantly different at the 0.05 level of probability.

Table 5. Cumulative total okra yield from application of 269 Mg/ha yard waste compost treatments.

Yard Waste Compost Treatment	Amount	Experiment Location, 1993: Green Acres	Haufler Farm	Average
	Mg/ba	kg/ha		
Conv. till incorporated	269	290 a*	1,778 a	1,030
No-till mulch	269	240 a	410 b NS	320
Conv. till control	0	359 a	600 a NS	480
Average		290	930	

NS = Average values between experiment locations are not significantly different at the 0.10 level of probability.

* Average values between experiment locations are significantly different at the 0.10 level of probability. Average values among yard waste compost treatments within a location not followed by the same letter are significantly different at the 0.10 level of probability.

Table 6. Cumulative total okra yield from application of 269 Mg/ha yard waste compost treatments, Green Acres, 1994.

Yard Waste Compost Treatment	Amount	Crop Establishment Method: Transplanted	Seeded	Average
	Mg/ha	kg/ha		
Conv. till incorporated	269	2,270 a	340 a*	1,310
No-till mulch	269	450 b	30 a NS	240
Conv. till control	0	610 b	40 a NS	330
Average		1,110	140	

NS = Average values between experiment locations are not significantly different at the 0.10 level of probability.

* Average values between crop establishment methods are significantly different at the 0.05 level of probability. Average values among yard waste compost treatments within a crop establishment method not followed by the same letter are significantly different at the 0.10 level of probability.

Supplemental Nitrogen Fertilizer for No-Till Tobacco Following Simulated Excessive Rainfall

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Abstract

Soil erosion and nitrates can both result in environmental pollution without good crop production management. The objective of this research was to determine the feasibility of no-tillage transplanting flue-cured tobacco *(Nicotiana tabacum)* into a winter cover crop of rye *(Secale cereale)*, and to determine the supplemental N required by growing tobacco following a large simulated rainfall event under two weed control treatments. Tobacco was no-tillage transplanted into killed rye cover crop using an in-row subsoil no-tillage planter followed by a conventional one-row Mechanical Brand Transplanter in a second operation. The no-tillage transplanting procedure worked well. Diagnostic leaf N concentration, leaf yield, and leaf N content were increased by as much as 15%, 27%, and 38%, respectively, by the use of a chemical herbicide compared to the control. High rainfall/irrigation of 4 total inches in a 2-day period just prior to flowering resulted in supplemental N requirement of about 50 lb/acre. This high response to supplemental N indicated that previous fertilizer N had been lost from the root zone.

Introduction

Soil erosion can be excessive from conventional tillage flue-cured tobacco *(Nicotiana tabacum* L.) (Doyle and Worsham, 1986). No-tillage transplanting of tobacco into winter cover crops has been successful in North Carolina (Doyle and Worsham, 1986; Wiepke, et al., 1988) and is presently receiving new emphasis in North Carolina (Worsham, 1995), Tennessee (Fowlkes, 1995; Drueger, et al., 1995) and Kentucky (Pearce, 1995; Pearce, et al., 1995) as well as this work in Florida.

This continued and renewed emphasis on conservation tillage for tobacco as well as other crops is in part due to actions of the U.S. Congress in the passage of the Food Security Act (1985) and the Food, Agriculture, and Conservation Trade Act (1990). The Food Security Act (1985) required farmers who want to remain eligible for USDA program benefits and are farming highly erodible land to develop, actively apply and fully implement a conservation plan according to schedule by the end of 1994. The Food, Agriculture, and Conservation Trade Act (1990) reinforced these farm management requirements first required by the Food Security Act (1985).

Precise and timely application of N fertilizer to crops grown on sandy soil is important in order to reduce leaching and economic losses by farmers as well as possible ground water pollution from nitrates. Excessive rainfall or irrigation can leach applied N from root zones of soils used for tobacco in Florida and can be avoided to some extent by using multiple sidedress applications of N (Smith, 1980) or corrected by replacement of the leached N (Persow and Whitty, 1982). Leaching losses can be excessive from heavy rainfall events in Florida and corn *(Zea mays* L.) and grain or forage sorghum *(Sorghum bicolor* L. Moench) responded best to N being applied in three or four split applications from planting to layby (Gallaher, et al., 1992; Lang, 1994). Winter cover crops in succession multiple cropping systems have been found to be effective in reducing nitrate leaching (Hargrove, et al., 1992) and many cover crops can provide substantial supplemental N (Gallaher, 1993). The objectives of this research were to determine the feasibility of no-tillage transplanting flue-cured tobacco into a winter cover crop of rye and determine the supplemental N required by growing tobacco following a large simulated rainfall event under two weed control treatments.

Materials and Methods

The field experiment was conducted in 1994 at the University of Florida's Green Acres Agronomy Farm near Gainesville, Florida. 'Wrens Abruzzi' rye was drilled into a harrowed seedbed at 90 lb/acre in November 1993 on an Arredondo fine sand (fine-sandy siliceous, Hyperthermic Grossarenic Paleudult). Rye received 500 pounds per acre of

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12(N)-4(P_2O_5)-8(K_2O) Jan. 10, 1994 and 2 pints 2-4-D/acre to control winter broadleaf weeds Jan. 24 1994.

Two pints Gramoxone@(F'araquat)/acre plus labeled rate of nonionic surfactant were broadcast over the rye at early anthesis on April 7, 1994. Rows 48 inches wide were laid off on April 11 using an in-row subsoil no-tillage planter (Brown-Harden). This unit did a strip tillage 12 inches deep under the row and prepared a clean seedbed in the standing rye about 4 to 6 inches wide over the row. Rye was partially pressed down in the middles, especially near the strip-tilled areas. Flue-cured tobacco, cultivar 'K326,' was transplanted at a spacing of 16 inches into the subsoil strips with a one-row Mechanical Brand Transplanter on April 12. The transplanter had to be operated in the same direction as the no-tillage subsoil unit in order to eliminate dragging and disruption due to the compressed rye. Fertilization consisted of 650 lb/A 6(N)-6(Pz05)-18(K_2O) on April 28, 650 lb/A 6(N)-6(P,0,)-18(K_2O) on May 9, and 300 Ib/A 6(N)-6(P_2O_5)-19(K,0) on May 16. This represented a total of 96 lb N/acre and, under normal circumstances, should have been adequate for maximum flue-cured tobacco production under Florida conditions (Stocks and Whitty, 1992).

Whole-plot treatments consisted of application of the herbicide Poast@ (sethoxydin) broadcast on April 18 at 1 pint formulated product/acre with a nonphytotoxic oil versus a control that received no weed control. Subplot treatments consisted of a supplemental sidedress application of N as ammonium nitrate at rates of *0*, 25, 50, and 75 lb N/acre. The sidedress N was applied June 19 followed by 0.2 acre-inch of irrigation to immediately move the N into the root zone. Rainfall was supplemented by overhead sprinkler irrigation as needed once or twice per week. The supplemental N was applied following a few days of heavy rainfall (1 acre-inch on June 18) and irrigation, which simulated 2 acre-inches of rainfall on June 18 and an additional 1 acre-inch on June 19.

The final subplot area was 22 feet long and 48 inches wide. Tobacco was topped at early flowering. Suckers were chemically controlled by a broadcast spray of 3 lb ai/A Maleic hydrazide [MH(WSSA)] immediately after topping. One week following topping, the topmost leaf was collected at random from six plants in each subplot for N analysis. The end plants were removed between plots prior to harvest, leaving **15** plants per 20 feet long subplots. Bottom leaf harvest was on July 13 and top leaf harvest was on July 27. Leaves were cured in a commercial tobacco barn. Stalks were harvested on July 27. All leaves and stalks were dried at 70 "C in a forced-air oven until dry, weighed, chopped as necessary, and ground to pass a 2-mm stainless steel screen using a Wiley mill. Samples were stored in sterile airtight plastic bags.

Nitrogen analysis consisted of weighing 100 mg of dry ground tobacco into 1-inch diameter 100-ml Pyrex test tubes. A salt catalyst mixture (2.3 g K_2SO_4:$CuSO_4$ in an 8:1 ratio), 2 glass boiling beads, and 10 ml of concentrated H_2SO_4 was added to each tube and mixed on a vortex mixer. The tubes were placed in an aluminum digestion block (Gallaher, et al., 1975), predigested by the careful addition of 2 mL of concentrated H_2O_2, and tubes covered with small glass funnels. Samples were digested for 3.5 hours, cooled, diluted with distilled water, cooled and brought to 75 mL of volume, and stored in Nalgene storage bottles. Nitrogen was determined colorimetrically using an autoanalyzer.

Data were tabulated, transformed as necessary, and ASCII files prepared using Quattro Pro@ (1987). Analysis of Variance was conducted using Mstat? (1985). The tables and manuscript were finalized using Wordperfect@ (1990).

Results and Discussion

The no-tillage subsoil strip-tillage transplanting of tobacco was successful with 100% survival of the seedlings. Tobacco plants appeared to have good root systems and experienced no lodging from the subsoil management. Farmers who are interested in this management should be able to utilize an in-row subsoil no-tillage planter with the transplanter units attached to the subsoiler frame. Because of the long distance from the rear of the tractor to the seats on the transplanter, one or two hydraulic helper wheels on the transplanter would likely be necessary to achieve successful planting in one operation.

The total N applied in the complete fertilizer was 96 lb/Acre and should have been adequate for high yield tobacco under Florida conditions. Leaf analysis showed that average N concentration increased by 76% from the 0 lb N/A treatment to the 75 lb N/A treatment (Table **1).** This indicated that either not enough N was applied or that the excess rainfall/irrigation did, in fact, leach N below the tobacco roots. Leaf N was in greater concentration for the herbicide-treated plots compared to the check at all levels of N fertilizer applied. This indicated that the greater numbers of weeds in the check plots were competing with tobacco for N. Leaf N appeared to approach sufficient levels (Jones et al., 1991) at the 50 lb N/A rate in the herbicide treated plots but would require 75 lb N/A or greater fertilizer N in the check plots.

Nitrogen concentration in the diagnostic leaf was positively related to dry matter yield (Tables **1** & 2). Leaf yield responded to 50 lb supplemental N/A, stalk yield to between 25

Table 1. No-tillage tobacco leaf N concentration from weed control and supplemental N treatments. Florida 1994.

Herbicide Applied	Plant Part	Nitrogen Rate, lb/acre 0	25	50	75	Average
			%			
Yes	Leaves	2.04	2.38	3.25	3.14	2.85*
No	Leaves	1.79	2.23	2.84	3.00	2.47
Average	Leaves	1.91 d	2.30 c	3.05 b	3.37 a	

LSD Q 0.05 p among N means = 0.29
CV subplot N means = 10.54%
* = significant difference between herbicide means Q 0.05 ɪ,

Values among average N means not followed by the same letter are significantly different according to LSD test at the 5% level. No significant interactions occurred between weed control treatments and N treatments.

and 50 lb N/A and whole plant yield to 25 Ib N/A (Table 2). Herbicide treatment resulted in greater leaf and total plant yield compared to the check. The leaf to stem dry matter ratio indicated that the supplemental N was required in greater quantities for leaf dry matter production compared to the stem (Table 2). This would be expected since the stem would develop first during plant growth and development and would have had access to an assumed sufficient level of fertilizer N prior to the excess rainfall/irrigation time.

Twice as much N was recovered in the leaf dry matter at the 50 lb supplemental N/A rate compared to the control (Table 3). This relationship held true for the total plant as well. Consistently greater amounts of N was removed by tobacco parts and total plant from the herbicide-treated plots compared to the control (Table 3).

Table 2. No-tillage tobacco plant dry matter yield from weed control and supplemental N treatments, Florida 1994.

Herbicide Applied	Plant Part	Nitrogen Rate, lb/acre 0	25	50	75	Average
		lb dry matter/acre				
Yes	Leaves	1,182	1,764	1,896	1,736	1,645*
No	Leaves	931	1,107	1,631	1,482	1,288
Average	Leaves	1,056 c	1,436 b	1,764 a	1,609 ab	

LSD Q 5% level among N means = 317
CV subplot N means = 20.64%
* = significant difference between herbicide means Q 5% level

Herbicide Applied	Plant Part	0	25	50	75	Average
		lb dry matter/acre				
Yes	Stalks	1,057	1,484	1,402	1,471	1,354 NS
No	Stalks	1,048	1,013	1,448	1,260	1,192
Average	Stalks	1,052 b	1,249 ab	1,424 a	1,366 a	

LSD Q 5% level among N means = 275
CV subplot N means = 20.60%
NS = **No** significant difference between herbicide means Q 5% level

Herbicide Applied	Plant Part	0	25	50	75	Average
		lb dry matter/acre				
Yes	Plant	2,239	3,249	3,298	3,207	2,998*
No	Plant	1,979	2,120	3,079	2,743	2,480
Average	Plant	2,109 b	2,685 a	3,189 a	2,975 a	

LSD Q 5% level among N means = 561
CV subplot N means = 19.51%
* = significant difference between herbicide means Q 5% level

Herbicide Applied	Plant Part	0	25	50	75	Average
		dry matter, leaf/stem ratio				
Yes	Plant	1.14	1.19	1.36	1.19	I.22*
No	Plant	0.88	1.11	1.14	1.19	1.08
Average	Plant	1.01 b	1.15 ab	1.25 a	1.19 a	

LSD Q 5% level among N means = 0.15
CV subplot N means = 12.53%
* = significant difference between herbicide means Q 5% level

Values among average N means not followed by the same letter are significantly different according to LSD test at the 5% level. No significant interactions occurred between weed control treatments and N treatments.

Summary and Conclusions

Erosive soils and national U.S. policy may necessitate that some farmers adapt conservation tillage management for tobacco as has been done for other crops. This study demonstrated that no-tillage subsoil transplanted tobacco into rye cover crop could be successful in Florida. Modification of existing equipment should make this management practical for erosion-prone soils. Weed control is essential to reduce competition with tobacco under these conditions. The herbicide treatment consistently gave larger leaf N concentrations, dry matter yield and N removal by the crop. More experimentation with herbicide treatments is needed. Even the herbicide treatment had some weeds that may have been controlled with a second application of the same herbicide.

Table 3. No-tillage tobacco plant N content from weed control and sumlemental N treatments, Florida 1994.

Herbicide Applied	Plant Part	Nitrogen Rate, lb/acre 0	25	50	75	Average
		lb N/acre				
Yes	Leaves	19.9	31.1	40.3	42.8	33.5*
No	Leaves	15.1	18.7	31.7	31.7	24.3
Average	Leaves	17.5 b	24.9 b	36.0 a	37.3 a	

LSD Q 5% level among N means = 8.1
CV subplot N means = 26.79%
* = significant difference between herbicide means Q 5% level

Herbicide Applied	Plant Part	0	25	50	75	Average
		lb N/acre				
Yes	Stalks	8.7	13.9	17.0	20.2	17.0+
No	Stalks	8.6	8.6	14.1	12.6	11.0
Average	Stalks	8.6 c	11.3 bc	15.5 ab	16.4 a	

LSD Q 5% level among N means = 4.4
CV subplot **N** means = 32.20%
* = significant difference between herbicide means Q 10% level

Herbicide Applied	Plant Part	0	25	50	75	Average
		lb N/acre				
Yes	Plant	28.6	45.0	57.3	63.1	48.5*
No	Plant	23.7	27.3	45.9	44.4	35.3
Average	Plant	26.1 b	36.2 b	51.6 a	53.7 a	

LSD Q 5% level among N means = 12
CV subplot N means = 27.20%
* = significant difference between herbicide means Q 5% level

Herbicide Applied	Plant Part	0	25	50	75	Average
		N content, leaf/stem ratio				
Yes	Plant	2.31 a*	2.36 aNS	2.45 aNS	2.14 **aNS**	2.32
No	Plant	1.73 b	2.18 ab	2.25 a	2.54 a	2.18
Average	Plant	2.02	2.27	2.35	2.34	

LSD Q 5% level among N means = 12
CV subplot N means = 27.20%
* = significant difference between herbicide means @ 5% level

Values among average N means within a weed treatment not followed by the same letter are significantly different according to LSD test at the 5% level.
* and NS = Significant and nonsignificant difference, respectively between weed treatments within a N treatment at the 5% level.

Excess application of water from either rainfall, irrigation, or both can result in losses of fertilizer N either due to leaching or erosion. Tobacco leaf and whole plant yield was improved by as much as 75% from application of supplemental N in this study. This indicated that either not enough N was applied in the complete fertilize; management or, what was more likely, that the excess water received by the crop resulted in leaching of the N out of the tobacco root zone. Based on the results of this study it is recommended that 50 Ib supplemental N/A be sidedressed immediately on tobacco, if rainfall/irrigation amounts of 3 acre-inches or more are received in a 3-day period within a 2- to 3-week period prior to flowering.

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Literature Cited

1. Doyle, S.L., and A.D. Worsham. 1986. Reducing soil erosion in tobacco fields with no-tillage transplanting. J. Soil and Water Cons. 41:193-196.
2. Food Security Act. 1985. 16 USC 3801 et seq. Inclusive of Public Law 99-98 and Public Law 101-624. U.S. Government Printing Office, Washington, DC.
3. Food, Agriculture, and Conservation Trade Act. 1990. Public Law 101-624. U.S. Government Printing Office, Washington, DC.
4 Fowlkes, D.J. 1995. No-till burley tobacco research in Tennessee: A team Approach. Univ. of Tennessee, Knoxville. Proceedings Abstracts of the 36th Tobacco Workers' Conference, January 9-12, 1995, Tampa, FL.
5. Gallaher, R.N., C.O. Weldon, and J.G. Futral. 1975. An aluminum block digester for plant and soil analysis. Soil Sci. SOC. Amer. Proc. 39~803-806.
6. Gallaher, R.N., T.A. Lang, K. Gallaher, and E.L. Ashburn. No-tillage tropical corn yield response to nitrogen fertilizer. pp. 30-33. *In* M.D. Mullen and B.N. Duck (eds). Proceedings of the 1992 Southern Conservation Tillage Conference. Jackson and Milan, Tennessee, July 21-23. Special Publication 92-01. Univ. of Tennessee Agric. Exp. **Sta.,** Knoxville, TN.
7. Hargrove, W.L., J.W. Johnson, J.E. Box, Jr., and P.L. Raymer. 1992. Role of winter cover crops in reduction of nitrate leaching. pp. 114-119. *In* M.D. Mullen and B.N. Duck, (eds). Proceedings of the 1992 Southern Conservation Tillage Conference. Jackson and Milan, TN, July 21-23. Special Publication 92-01. Univ. of Tennessee Agric. Exp. Sta., Knoxville, TN.
8. Jones, J.B., Jr., B. Wolf, and H.A. Mills. 1991. Plant Analysis Handbook: A Practical Sampling, Preparation, Analysis, and Interpretation Guide. Micro - Macro Publishing, Inc. 183 Paradise Blvd, Suite 108, Athens, GA.
9. Krueger, W., B. Kirksey, D.J. Fowlkes, and P. Hunter. 1995. Weed control in no-till burley tobacco; results and desirable development. Univ. of Tennessee, Knoxville. Proceedings Abstracts of the 36th Tobacco Workers' Conference, Jan. 9-12, 1995, Tampa, FL.
10. MSTAT 4.0. 1985. Users Guide to MSTAT. Version 4.0. Michigan State Univ., Lansing, MI. 11. Pearce, B. 1995. F6285 evaluation in no-till. Univ. of Kentucky. Proceedings Abstracts of the 36th Tobacco Workers' Conference, Jan. 9-12, 1995, Tampa, FL.
12. Pearce, B., *G.* Palmer, and Jack Zelezik, Univ. of Kentucky. Proceedings Abstracts of the 36th Tobacco Workers' Conference, Jan. 9-12, 1995, Tampa, FL.
13. Persow, G.D., and E.B. Whitty. 1982. Yield and quality of flue-cured tobacco as affected by nitrogen fertilization. Proc. Soil and Crop Sci. SOC. FL. 41:111-114.
14. QUATTRO PRO 4.0. 1987. Manual for QUATTRO@ PRO 4.0, Getting Started. Borland International, Inc., 1800 Green Hills Road, P.O. Box 660001, Scotts Valley, CA.
15. Smith, W.D. 1980. Yield and quality of flue-cured tobacco as affected **by** nitrogen rates and number of applications. MS Thesis, Univ. of Florida. 61 pp.
16. Stocks, G.R., and E.B. Whitty. 1992. Delayed topping effects on photoperiod-sensitive flue-cured tobacco. Tob. Sci. 36:21-23.
17. Wiepke, T., A.D. Worsham, and R.W. Lemons. 1988. Effect of hairy vetch, crimson clover, and rye cover crops on yield and quality of no-till fluecured tobacco in North Carolina. pp. 86-88. *In* K. H. Remy, *ed.* Proceedings, 1988 Southern Conservation Tillage Conference. Special Bull. 88-1. Mississippi Agric. & Forestry Exp. Sta., Mississippi State, MS.
18. WordPerfect Version 5.1. 1990. WordPerfecP for IBM Personal Computers and **PC** Networks. WordPerfect Cop., 1555 N. Technology Way, Orem, Utah.
19. Worsham, A.D. 1995. Update on no-till tobacco in North Carolina. North Carolina State Univ. Proceedings Abstracts of the 36th Tobacco Workers' Conference, Jan. 9-12, 1995, Tampa, FL.

Effect of Tillage and Liming on Nematode Populations

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Abstract

The effects of tillage and liming on plant-parasitic nematodes were determined in a split-plot experiment with soybeans *(Glycine max* [L.] Merr.) in north Florida. Main plot treatments were no-tillage or conventional-tillage, and subplots were amended with lime at rates of 0, 1,000, 2,000, 3,000, or 4,000 lb/A. Population densities of ring *(Criconemellu ornata* [Raski] Luc and Raski), root-knot *(Meloidogyne incognita* [Kafoid and White] Chitwood), and stubby-root nematodes *(Paratrichodorus minor* [Colbran] Siddiqi) were significantly greater in no-tillage plots than in conventional-tillage plots, but densities of the lesion nematode *(Pratylenchus scribneri* Steiner) were greater in conventional-tillage plots. Liming affected soil pH, but did not affect nematode densities or soybean yield, which were greater in no-tillage plots than in conventional-tillage plots.

Introduction

Plant-parasitic nematodes are important pests of soybean and other agronomic crops grown in the southeastern United States (Johnson, 1982; Riggs and Niblack, 1993). With the decline and limitation of nematicide usage, it is essential to develop effective alternative practices for nematode management (McSorley, 1994) and to examine the effects of common agricultural practices on plant-parasitic nematode populations. In north Florida, crop rotation (McSorley and Gallaher, 1993) or use of certain winter cover crops (McSorley et al., 1991) can reduce densities of some nematode species. Crop rotation has been much more effective than tillage in lowering densities of plant-parasitic nematodes (McSorley and Gallaher, 1994a).

In general, effects of tillage practices on nematode populations have been somewhat inconsistent and deserving of further investigation (Minton, 1986). Although nematodes may be affected by extremes in pH, the consequences of liming on nematode populations have been little studied (McSorley and Gallaher, 1994b); Norton, 1978). The objective of the research reported here was to compare the effects of tillage and liming on population densities of plant-parasitic nematodes on a sandy soil in north Florida.

Materials and Methods

The experiment was conducted during 1990-91 at the University of Florida Green Acres Agronomy Research Farm in Alachua County on a Bonneau fine sand (91% sand, 4% silt, 5% clay). The design was a split-plot, with two levels of tillage (conventional vs. no-tillage) as main plots and five rates of lime as subplots. Following removal of a corn *(Zea mays* L.) crop in the fall of 1990, dolomitic limestone was applied to subplots (10 feet wide x 30 feet long) at rates of 0, 1,000, 2,000, 3,000, or 4,000 lb/A. A winter cover crop of wheat *(Triticum aestivum* L.) was planted in November 1990 and harvested in April 1991. Crop residues were then mowed and sprayed with 2.0 Ib ai/A of glyphosate. Plots receiving the conventional tillage treatment were rototilled twice in April/May. On May 28, 'Howard' soybeans were planted directly into all plots (conventional-tillage and notillage with wheat stubble) with a two-row Brown-Harden Superseeder. Each subplot consisted of four rows, 30 inches apart and 10 feet long; each treatment combination was replicated four times. Crop management is described in detail elsewhere (McSorley and Gallaher, 1994b).

All subplots were sampled for nematodes on June 11 and October 15. Each soil sample consisted of six cores (1.0-inch diameter x 8-inches deep) collected from the center two rows of a subplot and combined into a plastic bag for transport. In the laboratory, a 100 cm3 (ca. 0.2 pt) soil subsample was removed for nematode extraction using a modified sieving and centrifugation procedure (Jenkins, 1964). Nematodes were identified and counted under a dissecting microscope, and nematode count data were log-transformed before conducting an analysis of variance (ANOVA), but arithmetic means rather than transformed means are presented in the tables.

A portion of each soil sample was air-dried and screened, and soil pH was determined from a 1:2 soil solution ratio in water using a glass electrode. Soil nutrient analyses were also conducted and reported elsewhere (McSorley and Gallaher, 1994b). Soybean yields were determined by harvesting the middle two rows of each plot in mid-October.

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Table 1. Effects of tillage and lime rate on population densities of ring nematodes *(Criconemella ornata* at planting and harvest of soybeans.

Lime rate (lb/A)	Nematodes per 100 cm3 soil June 11 No tillage	Conv. tillage	October 15 No tillage	Conv. tillage
0	305	146	179	102
1,000	236	200	167	168
2,000	232	186	192	201
3,000	205	104	217	207
4,000	238	343	283	73
Mean	243	196	208	150
ANOVA effects:				
Tillage	ns		*	
Lime	ns		ns	
Tillaee x lime	ns		ns	

* Analysis of variance (ANOVA) effect significant at P ≤ 0.05; ns = not significant.

Table 2. Effects of tillage and lime rate on population densities of root-knot nematodes *(Meldogyne incognita)* at planting and harvest of soybeans.

Lime rate (lb/A)	Nematodes per 100 cm3 soil June 11 No tillage	Conv. tillage	October 15 No tillage	Conv. tillage
0	8	4	101	102
1,000	13	5	810	53
2.000	37	2	92	51
3,000	18	5	212	60
4,000	34	8	127	75
Mean	22	5	268	68
ANOVA effects:				
Tillage	**		*	
Lime	ns		ns	
Tillage x lime	ns		ns	

*, ** Analysis of variance (ANOVA) effect significant at P ≤ 0.05 and P ≤ 0.01, respectively; ns = not significant.

Table 3. Effects of tillage and lime rate on population densities of stubbyroot nematodes *(Paratrichodorus minor)* at planting and harvest of soybeans.

Lime rate (lb/A)	Nematodes per 100 em3 soil June 11 No tillage	Conv. tillage	October 15 No tillage	Conv. tillage
0	37	17	47	28
1,000	58	22	26	27
2,000	44	24	38	24
3,000	38	27	30	42
4,000	28	17	53	30
Mean	41	21	39	30
ANOVA effects:				
Tillage	**		ns	
Lime	ns		ns	
Tillage x lime	ns		ns	

** Analysis of variance (ANOVA) effect significant at P ≤ 0.01; ns = not significant.

Results and Discussion

Population densities of the ring nematode were significantly lower in conventional-tillage plots than in no-tillage plots on one of two sampling dates (Table 1). The root-knot nematode showed a similar response, with lower densities in conventional-tillage plots on both sampling dates (Table 2), as did the stubby-root nematode, which was significantly lower in conventional-tillage plots on one sampling date (Table 3). None of these nematodes were affected by liming (Tables 1-3), even though the liming treatments resulted in a soil pH range from 5.9 (for the lime rate of 0 lb/A) to 6.6 (for the lime rate of 4,000 lb/A).

Unlike the other nematode species, the lesion nematode *(Pratylenchus scribneri* Steiner) was consistently more abundant under the conventional-tillage than under the no-tillage treatment (Table 4).

In the October sampling, a significant tillage x lime interaction was observed, with maximum numbers in the conventional-tillage subplots treated with 1,000 or 2,000 lb/A of lime (Table 4). This increase in abundance of *P. scribneri* under conventional tillage has been observed consistently in other locations and experiments (Alby et al., 1983; McSorley and Gallaher, 1994b). The reasons for this phenomenon are unknown, but could depend on the quality and degree of decomposition of the soybean roots, which the nematode inhabits (McSorley and Gallaher, 1994b). Other nematode species do not show this response, and in many cases are unaffected by tillage (McSorley and Gallaher, 1993; Minton, 1986) or favored by no-tillage, as observed here or in a previous study in Iowa (Thomas, 1978).

Soybean yields (Table 5) were significantly greater in no-tillage plots than in conventional-tillage plots, but were not affected by liming. Yields did not seem to be related to nema-

Table 4. Effects of tillage and lime rate on population densities of lesion nematodes *(pratylenchus scribneri* at planting and harvest of soybeans.

Lime rate (lb/A)	Nematodes per 100 cm3 soil June 11 No tillage	Conv. tillage	October 15 No tillage	Conv. tillage
0	4	74	111	96
1,000	44	70	140	727
2P00	22	42	234	528
3,000	42	91	223	479
4,000	50	55	258	344
Mean	32	66	193	435
ANOVA effects:				
Tillage			**	**
Lime			ns	ns
Tillage x lime			*	ns

*, ** Analysis of variance (ANOVA) effect significant at P ≤ 0.05 and P ≤ 0.01, respectively; ns = not significant.

Table 5. Effect of tillage and lime rate on yield of soybeans.

Lime rate (Ib/A)	Yield (bu/A)	
	No-tillage	Conventional tillage
0	34.3	25.7
1,000	34.3	19.3
2,000	37.5	17.2
3,000	29.0	18.2
4Po0	30.0	20.4
Mean	33.0	20.2
ANOVA effects:		
Tillage	**	
Lime	ns	
Tillage x Lime	ns	

** Analysis of variance (ANOVA) effect significant at P ■ 0.01; ns = not significant.

tode densities, because numbers of the most serious nematode parasite, *M. incognita,* and yields were both greater in no-tillage plots. Thus, while tillage practices may influence nematode populations, it does not seem practical to implement no-tillage practices for nematode management, but rather for other agronomic benefits.

Although tillage affected nematode population densities, liming had almost no effect on them. Many plant-parasitic nematodes appear to be well-adapted to the usual ranges in soil pH at which many field crops like soybeans are grown (McSorley and Gallaher, 1994b; Norton, 1978). According to our results, little effect on nematode populations should be expected if lime is applied to a site.

Literature Cited

Alby, T., J.M. Ferris, and V.R. Ferris. 1983. Dispersion and distribution of *Pratylenchus scribneri* and *Hoplolairnus galeatus* in soybean fields. J. Nematol. l5:418-426.

Jenkins, W.R. 1964. A rapid centrifugal-flotationtechnique for separating nematodes from soil. Plant Dis. Reptr. 48:692.

Johnson, A.W. 1982. Managing nematode populations in crop production. p. 193-203. *In* R.D. Riggs (ed.). Nematology in the Southern Region of the United States. Southern Coop. Ser. Bull. 276. Arkansas Agric. Exp. Stn., Fayetteville.

McSorley, R. 1994. Nematode management in sustainable agriculture. p. 517-522. In K.L. Campbell, W.D. Graham, and A.B. Bottcher (eds.). Environmentally Sound Agriculture, Proceedings of the Second Conference. Amer. SOC. Agric. Eng., St. Joseph, MI.

McSorley, R., and R.N. Gallaher. 1993. Population densities of root-knot nematodes following corn and sorghum in cropping systems. p. 26-29. *In* P.K. Bollich (ed.). Proc. 1993 Southern Conserv. Tillage Conf. for Sustainable Agriculture. Louisiana Agric. Exp. Stn. Ms. No. 93-86-7122, Monroe, LA.

McSorley, R., and R.N. Gallaher. 1994a. Effect of long-term rotation and tillage programs on plant-parasitic nematodes. p. 23-26. *In* P. J. Bauer and W. J. Busscher (eds.). Proc. 1994 Southern Conserv. Tillage Conf. for Sustainable Agriculture. USDA, ARS Coastal Plains Soil, Water, and Plant Res. Center, Florence, SC.

McSorley, R., and R.N. Gallaher. 1994b. Effect of liming and tillage on soil nematode populations under soybean. Soil Crop Sci. SOC. Florida Proc. 53:3135.

McSorley, R., R.N. Gallaher, and D.W. Dickson. 1991. Population densities of plant-parasitic nematodes following winter cover crop. **p.** 50-52. *In* T.C. Keisling *(ed.)*. Proc. 1991 Southern Conserv. Tillage Conf. Spec. Rept. 148, Arkansas Agric. Exp. Stn., Fayetteville.

Minton, N.A. 1986. Impact of conservation tillage on nematode populations. J. Nematol. 18:135-140.

Norton, D.C. 1978. Ecology of plant-parasitic nematodes. John Wiley and Sons, New York.

Riggs. R.D., and T.L. Niblack. 1993. Nematode pests of oilseed crops and grain legumes. p. 209-258. *In* K. Evans, D.L. Trudgill, and J.M. Webster (eds.). Plant Parasitic Nematodes in Temperate Agriculture. CAB International, Wallingford, UK.

Thomas, S. H. 1978. Population densities of nematodes under seven tillage regimes. J. Nematol. 10:24-27.

Nitrate Leaching as Affected by Tillage and Winter Cover Cropping

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Introduction

Heavy use of N resources in corn *(Zea mays* L.) production has been implicated as an extensive source of nitrate (NO_3-) delivered to ground and surface waters in the eastern United States (Hallberg, 1989). Since soil and crop management exert strong influence over NO_3- leaching (Russelle and Hargrove, 1989; Thomas et al., 1989), there is great need to assess NO_3- leaching losses under new corn production systems that are gaining acceptance. Research was undertaken to evaluate the effects of tillage [conventional tillage (CT) vs. no-tillage (NT)] and winter cover cropping (fallow vs. rye) on NO_3- leaching from land devoted to corn production.

Materials and Methods

The study is located at the USDA-ARS Southern Piedmont Conservation Research Center near Watkinsville, GA, The site consists of 12 instrumented, tile-drained plots located on nearly level (0-2% slope) Cecil sandy loam soil (clayey, kaolinitic, thermic Typic Kanhapludults). Each plot (32.8 feet wide 98.4 feet long) is underlain by five tile drains spaced 8.2 feet apart, which are installed on a 1% grade at a depth of approximately 3.3 feet. The border of each plot is enclosed with polyethylene sheeting that extends from the soil surface to the depth of the drain lines.

The volume of water drained from a plot is measured by tipping bucket, and recorded digitally with a datalogger. A small portion of the drainage flow ($<$ 3%) is removed by a sampling slot located between tipping-bucket halves. Drainage samples are collected and stored under refrigeration (35 °F) in the field by Isco Model 3700 FR sequential waste water samplers (Isco, Lincoln, NE). Tile effluent is analyzed for NO_3-.

During the summer of 1991, all plots were fertilized with 150 lb/A of N and conventionally tilled corn was grown. On Oct. 18, 1991, six plots were no-till planted to rye *(cv.* 'Wheeler'; 100 lb seed/A). The remaining six plots were left fallow. Rye dry matter production and N uptake were measured with samples taken on April 23, 1992, immediately prior to killing the rye, and imposing tillage treatments. CT plots were mowed, moldboard plowed and disked. NT plots were mowed, sprayed with paraquat, and left untilled. On April 24, 1992, plots were planted to corn (cv. 'DeKalb 689') in 30-inch rows at the rate of 24,390 kernels/acre. Fertilizer N (150lb N/A as NH_4NO_3) was broadcast 3 days later. On Oct. 7, 1992, corn grain was harvested and corn stover samples were taken from the two center rows of each plot. Corn tissue was dried, weighed, and analyzed for N. Years 2 and 3 began when rye was planted (cv. Wheeler; 100 lb seed/A) on Oct. 30, 1992 and Sept. 29, 1993, respectively. Rye was sampled and killed on April 12, 1993 (year 2) and April 20, 1994 (year 3). Conventional tillage was performed on April 13, 1993 (year 2) and April 19, 1994 (year 3). Corn (cv. DeKalb 689) was planted on all plots on April 14, 1993 (year 2) and April 20, 1994 (year 3), as it had been previously, and fertilizer N (150 lb N/A as NH_4NO_3) was broadcast immediately after planting. Corn was harvested and sampled as before for N analysis on Sept. 14, 1993 (year 2) and Sept. 13, 1994 (year 3). Year 3 concluded on Oct. 14 1994.

Results and Discussion

Winter 1991

Unusually dry fall conditions (Table 1) delayed soil moisture recharge, and prevented appreciable tile drainage until the end of December 1991 (Figure 1). Winter drainage was essentially complete by the end of February 1992. From then on, lower than normal spring rainfall (Table 1) and increasing evapotranspiration prevented significant drainage for the rest of the fallow period. Cumulative drainage was consistently less under rye than it was under fallow (Figure 1). By late April when the rye was killed, the difference in drainage volumes was considerable and significant ($P < 0.03$).

The concentration of NO_3-N in the drainage effluent was also consistently lower with the rye cover crop (Figure 1). Under rye, the average NO_3-N concentration of tile flow was 8.7 ppm NO_3-N, just below the U.S. Public Health Service's drinking water standard (10 ppm NO_3-N). In contrast, the average NO_3-N concentration measured under fallow was significantly greater (22.7 ppm NO_3-N; $P < 0.01$).

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Total NO_3-N loss in tile flow was less under rye (3.0 lb N/A) than under fallow (10.9 lb N/A; P < 0.01), though measured NO_3 leaching losses were small for both winter cover treatments. Reduction in NO_3-leaching by cover crops was related to their use of both water and N. Rye topgrowth averaged 2.47 tons/A when it was killed, and it contained 84 lb N/A.

Summer 1992

Despite below-normal rainfall for March, April, and May, above average amounts from June through September 1992

Table 1. Monthly rainfall from October 1991 through October 1994, and long-term (1884-1991) average monthly rainfall at Watkinsville, GA.

Year	Month	Measured monthly rainfall at site	Long-term average monthly rainfall*	Rainfall deficit (-) or surplus (+)
		(in)	(in)	(in)
1991	October	0.14	2.98	−2.84
	November	0.72	3.07	−2.35
	December	3.16	4.35	−1.19
1992	January	3.41	4.68	−1.27
	February	4.80	4.75	+0.05
	March	4.00	5.29	−1.29
	April	1.58	3.88	−2.30
	May	1.68	3.80	−2.12
	June	6.51	3.91	+2.60
	July	5.71	4.99	+0.72
	August	8.09	4.23	+3.86
	September	7.65	3.37	+4.28
	October	2.43	2.98	−0.55
	November	7.98	3.07	+4.91
	December	5.26	4.35	+0.91
1993	January	3.73	4.68	−0.95
	February	5.87	4.75	+1.12
	March	7.31	5.29	+2.02
	April	2.94	3.88	−0.94
	May	2.21	3.80	−1.59
	June	0.74	3.91	−3.17
	July	1.97	4.99	−3.02
	August	1.16	4.23	−3.07
	September	3.28	3.37	−0.09
	October	4.38	2.98	+1.40
	November	3.22	3.07	+0.15
	December	2.90	4.35	−1.45
1994	January	3.74	4.68	−0.94
	February	2.78	4.75	−1.97
	March	5.17	5.29	−0.12
	April	2.08	3.88	−1.80
	May	2.07	3.80	−1.73
	June	11.41	3.91	+7.50
	July	7.42	4.99	+2.43
	August	6.54	4.23	+2.31
	September	4.20	3.37	+0.83
	October	6.48	2.98	+3.50
Total		154.72	150.88	+3.84

* Measured 3 miles from site.

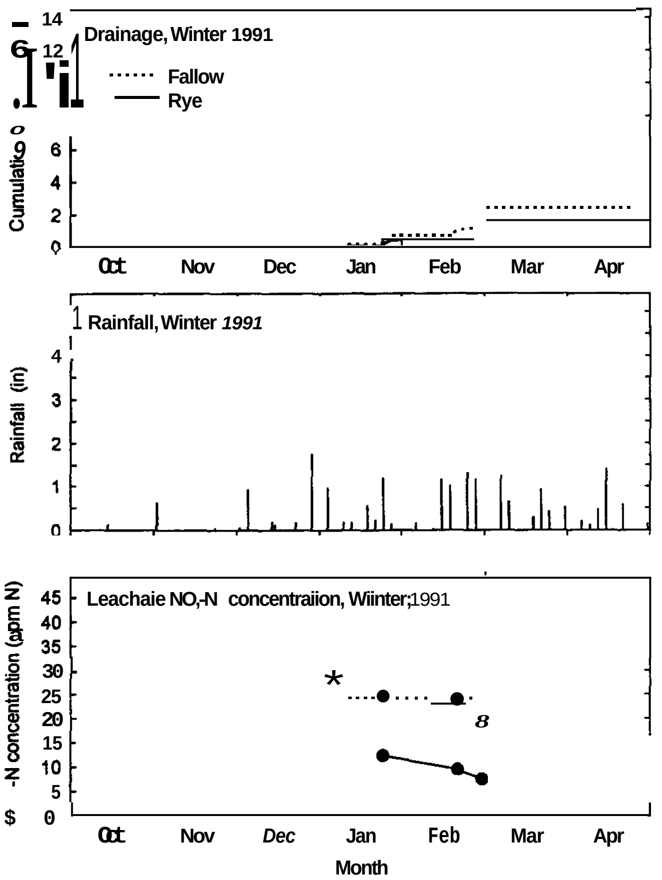


Figure 1. Cumulative drainage, rainfall, and leachate NO_3-N concentration for winter 1991.

(Table 1) generated considerable summer drainage (Figure 2). During summer 1992, cumulative drainage was greater where rye had been grown (7.8 inches for rye, 6.1 inches for fallow (P 0.08). However, during the same period, tillage had no significant effect on cumulative drainage (7.6 inches for NT, 6.3 inches for CT (P<0.35). Overall, the trend was greater summer drainage where surface coverage was greatest—on NT plots that possessed a mulch of both rye and corn residues (Figure 2).

Leachate NO_3-N concentrations were higher soon after drainage began in the summer, and lower at the end of the corn growing season (Figure 2). This trend probably reflects the seasonal pattern of N use by corn, and the fact that **N** fertilizer was applied in a single application at the beginning of the growing season. In addition, leachate NO_3-N concentrations during the first half of the summer period tended to be higher with NT than with CT (Figure 2). This tillage effect may be due to the presence of more macropores continuous with the soil surface under NT. Macropores can conduct large amounts of water and nitrate rapidly through root zone and deep into the profile, or beyond. The NO_3-N concentration of tile flow averaged across the entire summer tended to be higher with NT (16.9 ppm) than with CT (14.2 ppm; P<0.11).

In general, NO_3-N concentrations of the tile flow during summer were lower where rye had been grown (Figure 2). NO_3-N concentrations of tile flow averaged across the entire summer were lower for rye (13.2 ppm NO_3-N) than for fallow (18.0 ppm NO_3-N; $P<0.05$). These results probably reflect less NO_3-N present in the root zone of rye plots at the beginning of the corn growing season. Immobilization of N associated with the decomposition of rye residues also may have limited the amount of NO_3-N available for leaching under corn.

Unexpectedly, total NO_3-N losses in the tile flow were much greater during the corn growing season than they had been during the preceding winter period. This can be attributed to above average rainfall from June through September, and the leaching of fertilizer N applied for corn. During summer 1992, the trend was for greater NO_3-N leaching loss with NT (28 lb/A NO_3-N) than with CT (19 lb/A NO_3-N; $P<0.13$). However, there was no effect of previous cover crop on total NO_3-N leaching losses (24 lb/A NO_3-N for rye, and 24 lb/A NO_3-N fallow; $P<0.83$). Similarly, the interaction of tillage and previous cover crop had no significant effect on measured NO_3-N leaching losses during this period ($P\sim0.23$).

There were no significant effects of tillage ($P<0.71$), cover cropping ($P<0.45$) or their interaction ($P<0.99$) on corn N uptake (89 lb N/A for NT rye, 86 lb N/A for CT rye, 85 lb N/A for NT fallow, and 82 lb N/A for CT fallow). Similarly, there were no significant effects of tillage ($P<0.72$), cover cropping ($P<0.13$) or their interaction ($P<0.98$) on corn grain yield (102 bu/A for NT rye, 100 bu/A for CT rye, 111 bu/A for NT fallow, and 108 bu/A for CT fallow).

Winter 1992

The trend for above average rainfall during summer 1992 persisted through much of the subsequent winter season (Table 1). As a result significant drainage began about 6 weeks earlier than it did in winter 1991, and drainage occurred more or less continuously until the rye was killed (Figure 3). However, neither tillage ($P<0.45$), cover cropping ($P<0.36$), or their interaction ($P<0.52$) significantly affected total drainage during winter 1992.

The concentrations of NO_3-N in the drainage effluent were low relative to those measured for winter 1991 and summer 1992. Low NO_3-N concentrations during winter 1992 are attributable to good growth and N uptake by corn in response to abundant, well-distributed summer rain. NO_3-N concentrations averaged across the entire winter season were significantly affected by tillage (4.5 ppm for NT, 6.2 ppm for

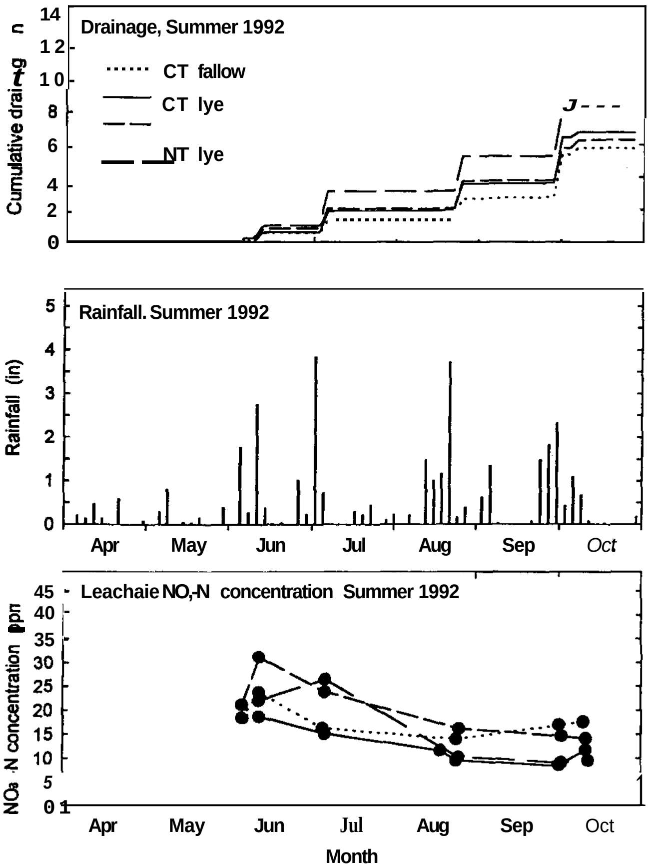


Figure 2. Cumulative drainage, rainfall, and leachate NO_3-N concentration for summer 1992.

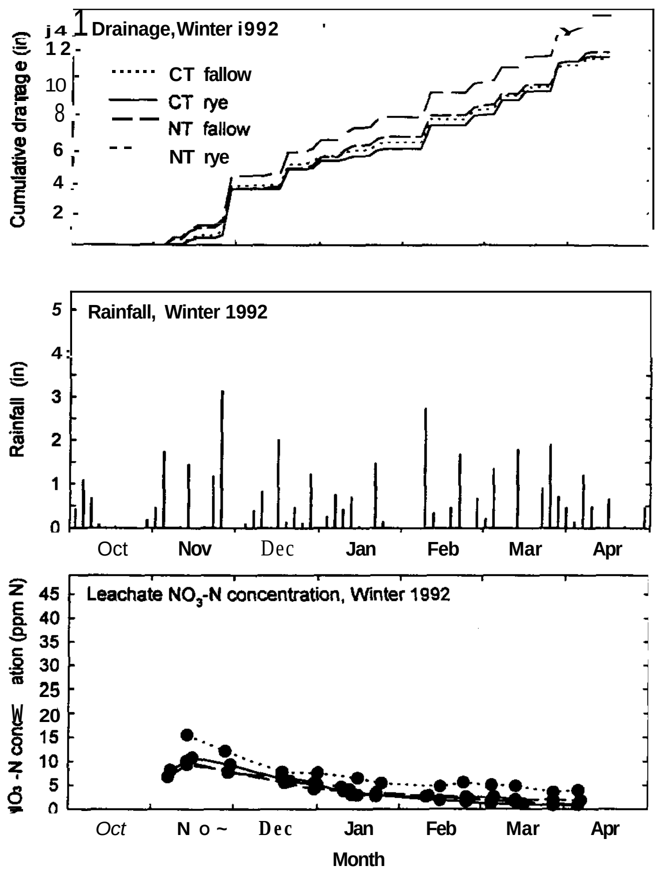


Figure 3. **Cumulative drainage, rainfall, and leachate NO_3-N concentration for winter 1992.**

CT; $P < 0.07$), cover cropping (4.6 ppm for rye, 6.1 ppm for fallow; $P<0.01$), and their interaction (4.6 ppm for NT rye, 4.6 ppm for CT rye, 4.4 ppm for NT fallow, 7.8 ppm for CT fallow; $P < 0.01$).

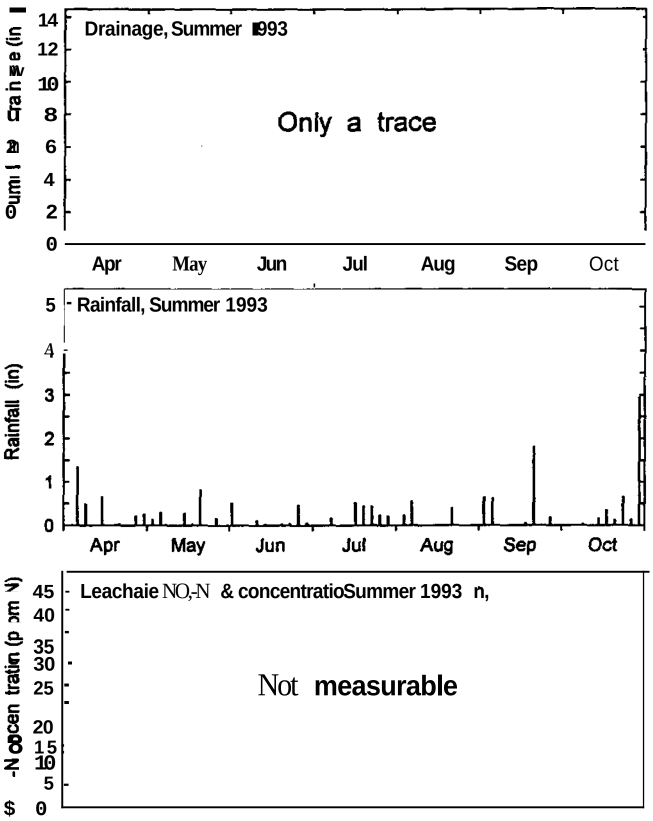
Total NO_3-N loss in tile flow was affected by tillage (13.0 lb/A for NT, 16.1 lb/A for CT; $P < 0.05$) and the interaction of tillage with cover cropping (14.5 lb/A for NT rye, 12.2 lb/A for CT rye, 11.5 lb/A for NT fallow, 19.9 lb/A for CT fallow; $P < 0.01$). The trend was for greater NO_3-N loss with fallow than with rye (13.4 lb/A for rye, 15.7 lb/A for fallow; $P < 0.13$). Above-ground dry matter production by rye was less with NT than with CT (0.42 ton/A for NT, 0.61 tons/A for CT; $P < 0.03$). Similarly, the N content of rye topgrowth was less with NT than with CT (15.8 lb/A for NT, 23.4 lb/A for CT; $P<0.02$).

Summer 1993

This corn growing season was one of the driest on record (Table 1, Figure 4). Only traces of drainage occurred, which provided insufficient sample volumes for NO_3-N analysis. Because of drought, corn N uptake was also greatly reduced, relative to uptake the previous summer season. Corn above-ground N content at harvest was not affected significantly by tillage (56 lb N/A for NT, 43 lb N/A for CT; $P < 0.40$) and cover cropping (54 lb N/A for rye, 45 lb N/A for fallow; $P < 0.18$) had no significant effect on corn N uptake. However, the interaction of tillage and cover cropping did affect corn N content at harvest significantly (66 lb N/A for NT rye, 43 lb N/A for CT rye, 47 lb N/A for NT fallow, and 43 lb N/A for CT fallow; $P < 0.07$). Greater N uptake by corn with NT rye was probably due to greater moisture conservation by the heavier mulch of this treatment. However, corn grain yields on all treatments were extremely low, and not significantly affected by tillage (11 bu/A for NT, 16 bu/A for CT; $P<0.51$), cover cropping (13 bu/A for rye, 13 bu/A for fallow; $P<0.99$), or their interaction (10 bu/A for NT rye, 16 bu/A for CT rye, 12 bu/A for NT fallow, 15 bu/A for CT fallow; $P<0.60$).

Winter 1993

Rainfall for winter 1993 was also less than average, though the deficit was not as large as for summer 1993 (Table 1). Total drainage during winter 1993 was significantly affected by tillage (4.30 inches for NT, 2.68 inches for CT; $P<0.05$). However, neither cover cropping (3.16 inches for rye, 3.82



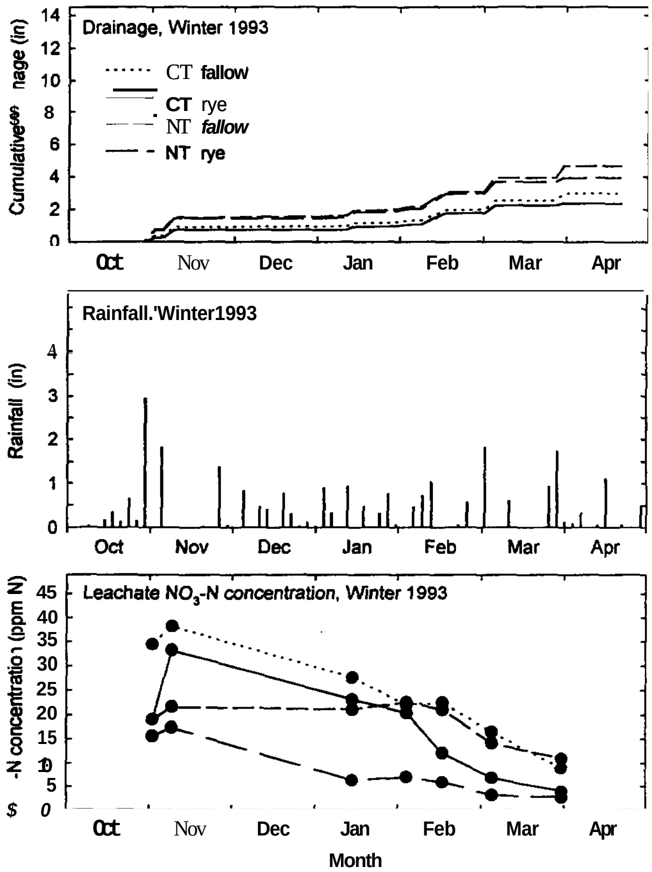


Figure 5. Cumulative *drainage*, rainfall, and leachate NO_3-N concentration for winter 1993.

inches for fallow; P<0.32), or its interaction with tillage (3.94 inches for NT rye, 2.37 inches for CT rye, 4.65 inches for NT fallow, 3.00 inches for CT fallow; P<0.95) had a significant effect on total winter drainage.

The concentrations of NO_3-N in the drainage effluent were relatively high during much of winter 1993 (Figure 5). Winter 1993 followed an exceptionally dry summer growing season, during which corn was unable to utilize applied N fertilizer efficiently, leaving much NO_3-N susceptible to leaching over the winter. NO_3-N concentrations averaged across the entire winter season were significantly affected by tillage (13.6 ppm for NT, 20.3 ppm for CT; P < 0.01), cover cropping (12.9 ppm for rye, 21.0 ppm for fallow; P < 0.01), but not their interaction (9.2 ppm for NT rye, 16.6 ppm for CT rye, 18.0 ppm for NT fallow, 24.0 ppm for CT fallow; P<0.47).

Total NO_3-N loss in tile flow was affected by cover cropping (8.7 lb N/A for rye, 17.7 lb N/A for fallow, P<0.04), but not by tillage (13.6 lb/A for NT, 12.8 lb/A for CT; P < 0.85) or the interaction of tillage and cover cropping (8.2 lb/A for NT rye, 9.2 lb/A for CT rye, 19.0 lb/A for NT fallow, 16.4 lb/A for CT fallow; P < 0.56). Neither above-ground dry matter production by rye (1.62 tons/A for NT, 1.68 tons/A for CT; P<O.48), nor above-ground rye N content (52.7 lb/A for NT, 63.0 lb/A for CT; P < 0.12) was affected significantly by tillage.

Summer 1994

In contrast to summer 1993, this corn growing season was much above average in rainfall (Table 1). Total drainage during summer 1994 was significantly affected by tillage (8.51 inches for NT, 5.80 inches for CT; P <0.01). However, neither cover cropping (P~0.15) or its interaction with tillage (P < 0.39) had a significant effect on total summer drainage.

The concentrations of NO_3-N in the drainage effluent were relatively low during summer 1994 (Figure 6). NO_3-N concentrations averaged for the summer were significantly affected by cover (4.39 ppm for rye, 5.52 ppm for fallow; P<0.01), but not by tillage (4.98 ppm for NT, 4.92 ppm for CT; P < 0.0.95), or the interaction of tillage and cover cropping (4.39 ppm for NT rye, 4.38 ppm for CT rye, 5.56 ppm for NT fallow, 5.47 ppm for CT fallow; P<0.83).

Total NO_3-N loss in tile flow during summer 1994 was not affected by cover cropping (8.1 lb N/A for rye, 7.6 lb N/A for fallow; P<0.77), tillage (9.6 lb N/A for NT, 6.1 lb N/A for CT; P<O.17), or their interaction (8.8 lb/A for NT rye, 7.3 lb/A for CT rye, 10.3 lb/A for NT fallow, 4.9 lb/A for CT fallow; P < 0.30). The combined N content of corn grain and stover at harvest was affected significantly by tillage (136 lb N/A for NT, 144 lb N/A for CT; P < 0.01) and cover cropping (125 lb N/A for rye, 155 lb N/A for fallow; P<O.O6), but not by the interaction of tillage and cover cropping (128 lb N/A for NT rye, 121 lb N/A for CT rye, 143 lb N/A for NT fallow, 166 lb N/A for CT fallow; P<O.25). Corn grain yield was significantly affected by cover cropping (151 bu/A for rye, 174 bu/A for fallow; P<O.O3), and the interaction

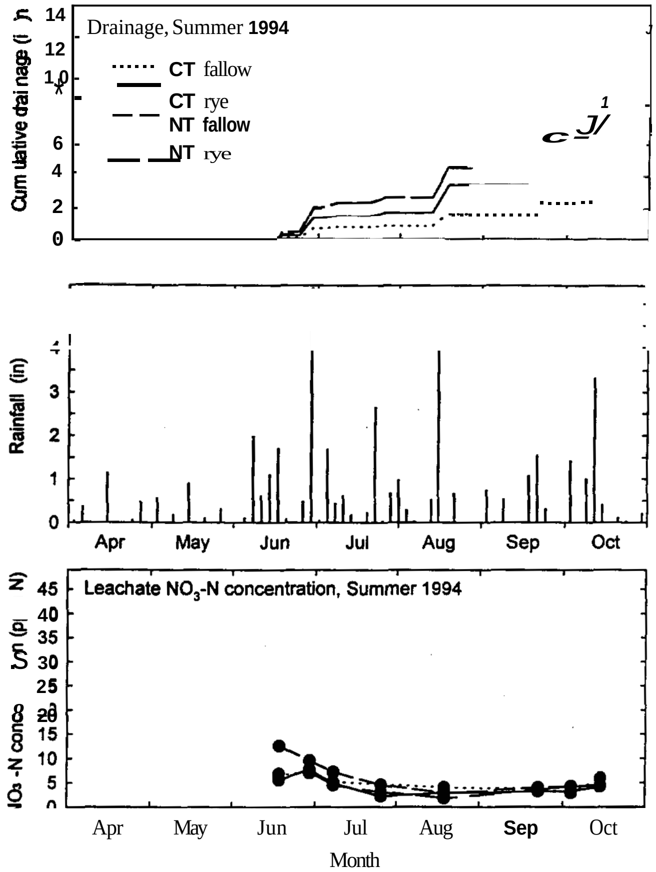


Figure 6 Cumulative drainage, rainfall, **and leachate NO,-N concentration for summer 1994.**

of cover cropping and tillage (162 bu/A for NT rye, 140 bu/A for CT rye, 160 bu/A for NT fallow, 188 bu/A for CT fallow; P < 0.02), but not by tillage (160 bu/A for NT, 164 bu/A for CT; P < 0.61).

In climates like Georgia's that possess mild, humid winters, cover cropping with rye has utility for control of NO_3^- leaching from cropland. Rye cover crops consistently reduced leachate NO_3-N concentrations, and limited NO_3-N leaching losses during winter. Our results indicate no consistent differences between NT and CT in their effect on NO_3^- leaching, and suggest that choice of tillage method on upland soils of the Southern Piedmont will have minor impact on groundwater quality.

Literature Cited

Hallberg, G.R. 1989. Nitrate in ground water in the United States. In R.F. Follett [ed.] Nitrogen management and ground water protection. Elsevier, New York, N.Y.

Russelle, M.P., and W.L. Hargrove. 1989. Cropping systems: Ecology and management. *In* R.F. Follett [ed.] Nitrogen management and ground water protection. Elsevier, New York, N.Y.

Thomas, G.W., M.S. Smith, and R.E. Phillips. 1989. Impact of soil management practices on N leaching. In R.F. Follett [ed.] Nitrogen management and ground water protection. Elsevier, New York, N.Y.

Corn Weed Management in Tall Fescue Sod

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Introduction

Tall fescue *(Festuca arundinaceae* Schreb.) has been planted as a desirable forage grass throughout much of the Midsouth for many years. More recently, it was the primary species planted into the Conservation Reserve Program (CRP) acreage because of its ability to establish quickly and provide an excellent ground cover to prevent soil erosion. Within the next few years, some of the acreage will be brought into production as the current CRP contracts end. Most of the acreage taken out of production in Kentucky and surrounding states is subject to erosion from the intense storms frequently encountered during the spring. Therefore, as these fields go back into production, it is desirable to utilize conservation tillage practices, such as no-tillage, to establish the desired crop.

No-tillage corn production into tall fescue sod has been practiced in Kentucky for more than 30 years. Atrazine plus paraquat and atrazine plus simazine plus paraquat became the grower standards in the late 1960's and early 1970's, and usually provided 100% control of the tall fescue sod and greater than 85% control of giant foxtail, smooth pigweed, and most other small-seeded annual weeds. In the late 1970's and early 19803, combinations of atrazine plus alachlor or metolachlor were commonly used, particularly where annual grasses such as large crabgrass and fall panicum were a problem. In the past 2 years, we have compared low rates of glyphosate to paraquat in combination with various residual herbicides. Glyphosate or paraquat combined with atrazine provide comparable control of the tall fescue.

While control of tall fescue is relatively easy, consideration of other items that affect weed management should be considered. Species such as brambles, trumpetcreeper, and eastern red cedar are examples of troublesome weeds present in CRP land that may be difficult to control in a growing crop. These species may be easier to control before planting the crop. Multiple herbicides and multiple applications may also be needed. Mowing is also an option that should be considered. A primary tillage operation might be useful from a weed management standpoint, but since most of the CRP acreage is erodible, tillage would be suggested only in rare cases.

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The renewed interest in planting corn into a tall fescue sod in land coming out of the CRP program caused us to examine historical data and to initiate additional research to answer some of the questions being received.

Methods and Materials

In this paper, rates for atrazine are expressed as a liquid because of the widespread use of AAtrex 4L@ and other liquid atrazine formulations. Some of the early research reported in this paper was conducted with Atrazine 80WP; however, for ease of discussion these rates have been converted to liquids.

Similarly, Princep 4L@ is used for all formulations of simazine. We have not observed any difference of tall fescue control with any of the various herbicide formulations. Likewise, Gramoxone Extra 2.5S is used because it is the paraquat formulation available today. The research reported in this paper, except for the data from the 1990's, was conducted with Paraquat 2S. These amounts are presented in pints of Gramoxone Extra *2.5s* for ease of comparing treatments across years. Therefore, for ease of discussion, herbicide rates are given in either pints or quarts and herbicide formulations currently available to growers.

Data in this paper were collected over a 27-year period at the University of Kentucky. All studies were conducted on experiment stations near Lexington or Princeton. In all studies, field corn was planted into a tall fescue sod with a no-tillage planter. The sod had been established for at least 5 years in all instances. Herbicide treatments were applied to small plots, generally 2 or 4 rows wide by 30 to 50 feet in length. The various herbicides were applied with flat fan nozzles. Unless otherwise indicated, all Gramoxone Extra treatments were applied in 25 gallons of water per acre and included X-77, a nonionic surfactant, at 0.25% vlv. These treatments were applied immediately after planting. The Roundup treatments were applied in 10 gallons of water per acre and were made 7 days before corn planting, unless otherwise indicated.

Control of tall fescue and weed species was evaluated on a 0 to 100 scale, with 0 being no control and 100 being weed free. Control evaluations were made 4 and 8 weeks after planting or treatment and at harvest.

Results and Discussion

Atrazine was used alone to control tall fescue before the introduction of Gramoxone Extra in the late 1960's. The atrazine was applied 3 or 4 weeks before corn planting. This early preplant application was necessary because it took that long for the atrazine to be leached into the root zone and kill the tall fescue. At least 3 qt/A of atrazine 4L were required to kill the tall fescue (Table 1). The addition of Gramoxone Extra allowed the grower to use less atrazine. Results of UK research in 1967 indicated that Gramoxone Extra combined with 2 qt/A of atrazine 4L killed tall fescue as well as 3 or 4 qt/A of atrazine 4L used alone (Table 1).

Tall fescue sods that have been established for several years often have only a few weed species that emerge and become a serious problem during the first season of corn. Two of these species that occur in Kentucky are giant foxtail and smooth pigweed. However, in subsequent years, many other weeds will emerge as the sod decomposes.

Many growers in Kentucky have used only atrazine and Gramoxone Extra to kill tall fescue, giant ragweed, and smooth pigweed. Greater than 80% control of all species can be expected (Table 2). A combination of atrazine, Princep, and Gramoxone Extra controlled these species similar to atrazine plus Gramoxone Extra (Table 3). The primary advantage of Princep was that it added a longer duration of giant foxtail control.

There has been an increased interest in using Roundup to control tall fescue in the past few years. Our initial tall fescue control with Roundup was at rates of 2 to 3 qt/A per acre using *25* to 40 gpa as a carrier volume. These data were collected in the 1970's and early 1980's. Since that time, it has been shown with numerous species that Roundup rates of 1.5 qt/A or less will provide excellent control at carrier volumes of 10 gpa or less. With this in mind, we conducted two studies in 1994 to: (1) evaluate Roundup at 1.0 and 1.5

Table 1. Tall fescue control 8 weeks after treatment (WAT) with atrazine and atrazine combinations in 1967.

Treatment[1,2]	Amount/Acre	Control 8 WAT
		(%)
Atrazine 4L	2 qt	13
Atrazine 4L	3 qt	80
Atrazine 4L	4 qt	98
Atrazine 4L + Gramoxone Extra *2.5s*	2 qt 0.8 pt	100
Atrazine 4L + Gramoxone Extra *2.5s*	3 qt 0.8 pt	100

[1]Atrazine used in this experiment was an 80WP formulation. The quantities were converted to an atrazine formulation currently available to farmers.
[2]Gramoxone Extra was applied with nonionic surfactant at 0.25% v/v.

Table 2. Tall fescue, giant foxtail, and smooth pigweed control over a 4-year period with Atrazine 4L at 2 qt/A and Gramoxone Extra 2.5s at 0.8 pt/A plus nonionic surfactant at 0.25% v/v. Control ratings were made 8 WAT.

Year	Tall Fescue	Giant Foxtail	Smooth Pigweed
		(% control)	
1978	100	82	88
1979	95	100	100
1980	100	100	100
1981	100	92	100

Table 3. Tall fescue, giant foxtail, and smooth pigweed control over a multi-year period with Atrazine 4L at 1.5 qt/A, Princep 4L at 1.5 qt/A, and Gramoxone Extra 2.5s at 0.8 pt/A plus nonionic surfactant at 0.25% v/v. Control ratings were made 8 WAT.

Year	Tall Fescue	Giant Foxtail	Smooth Pigweed
		(% control)	
1978	100	82	88
1979	95	100	100
1980	100	100	100
1981	100	92	100
1993	100	95	90
1994	100	95	95

Table 4. Tall fescue control with Roundup in 1994. All treatments included a nonionic surfactant at 0.5% v/v and were applied at 10 gpa 7 days before corn planting.

Treatment[1,2]	Amount/ Acre	Control[3] 4 WAP	Control[3] At Harvest
		(%)	
Roundup 4S	1 qt	89	95
Roundup 4S + Ammonium Sulfate	1 qt 0.5%	96	98
Roundup 4S + 2, 4-D LV4	1 qt 1 Pt	90	98
Roundup 4S + 2,4-D LV4 + Ammonium Sulfate	1 qt 1 Pt 0.5%	91	98
Roundup 4S	1.5 qt	99	99
Roundup 4S + Ammonium Sulfate	1.5 qt 0.5%	98	100
Roundup 4S + 2, 4-D LV4	1.5 qt 1 Pt	96	100
Roundup 4S + 2,4-D + LV4 Ammonium Sulfate	1.5 qt 1 Pt 0.5%	99	99
LSD*(.05)*		5	36

[1]The ammonium sulfate used was Cayuse@ and was applied at 0.5% v/v.
[2]All treatments received Bullet 4L0 at 4 qt/A immediately after corn planting.
[3]Visual control rating were made 4 weeks after planting (4 WAP) and at corn harvest.

qtfA, with and without various additives, and (2) determine if mowing before herbicide application helped or hindered tall fescue control and corn growth.

Tall fescue control 4 weeks after planting was slightly increased with the addition of ammonium sulfate to Roundup at 1.0 qt/A compared to Roundup alone at 1.0 qt/A. The control from Roundup at 1.0 qt/A plus ammonium sulfate was equal to that of Roundup alone at 1.5 qt/A (Table 4). At corn harvest, tall fescue control was equal among all the treatments.

Mowing the tall fescue to a height of 6 inches 2 weeks before application slightly enhanced tall fescue control with Roundup at 1.0 qt/A at the 4 weeks after planting evaluation (Table 5). Mowing did not change tall fescue control with Roundup at 1.5 qt /A or Gramoxone Extra at 1.6 pt/A. Tall fescue control at the time of corn harvest was excellent for all treatments.

Corn stands were significantly greater in plots that were mowed compared to plots that were not mowed (Table 5). Mowing appeared to have the greatest impact on corn stands in plots treated with Gramoxone Extra. Mowing may have improved corn stands by changing the habitat of rodents or other pests that feed on corn seed and emerging corn plants.

Our results over the years have shown that atrazine, or another triazine herbicide, in combination with Gramoxone Extra or Roundup, is needed to provide consistent tall fescue control. It is our opinion that corn would be the crop of choice in most of the CRP fields since corn can be established under no-tillage conditions and has been shown to provide yields equal to those obtained under tilled conditions.

Table 5. Effect of mowing in combination with Roundup or Gramoxone Extra on tall fescue control and corn stands. All Roundup treatments were applied at 10 gpa 7 days before corn planting and all Gramoxone Extra treatments were applied at 25 gpa immediately after planting. All treatments were applied with a nonionic surfactant at 0.5% vlv.

Treatment'	Amount/ Acre	Mowing	---- Control[3] --- 4WAP	Harvest	Corn3 Stand
			- - (%)	------	(No/A)
Roundup 4S	1 qt	No	95	96	10,963
Roundup 4S	1 qt	Yes	99	100	17,887
Roundup 4S	1.5 qt	No	98	100	14,956
Roundup 4S	1.5 qt	Yes	98	100	20,909
Gramoxone Extra 2.5s	1.6 pt	No	100	100	5,570
Gramoxone Extra 2.5s	1.6 pt	Yes	100	100	18,151
LSD(.O5)			2.6	NS	3,380

[1]All treatments received Atrazine 4L at 1.5 qt/A plus Dual Do at 1 qt/A immediately after corn planting.

Visual control ratings were made 4 weeks after planting (WAP) and at corn harvest.

T o m stands were determined 6 weeks after planting.

The Effects of Organic Matter and Tillage on Maximum Compactability

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Introduction

Hugo Kruger of the INTA Experiment Station at Bordenave, Argentina presented data at a no-tillage symposium in Paraguay in August 1994, showing that "maximum compactability" as measured by the Proctor test was related to tillage history of the soil samples. Samples from conventionally tilled plots showed highest bulk densities, no-tillage samples showed the lowest, and minimum tillage samples gave intermediate values. As a result of his observations, in the fall of 1994, we began to determine maximum compactability on samples from plots and fields with variable land use history in Kentucky. This paper is a report of the preliminary results.

Materials and Methods

Samples were taken from 0- to 2-inch depths at the following locations:

(1) Maury silt loam was sampled in the old no-tillage plots at Lexington (Ismail et al., 1994). Four treatments were sampled: no-tillage, 0 and 300 Ib N/acre rates and conventional tillage, and 0 and 300 lb N/A rates on each of four replications for a total of 16 samples. In addition, one sod sample from alongside the plots was taken.

(2) Lonewood loam was sampled at eight farm locations in Russell County, Kentucky. Treatments included sod, no-tillage, and conventionally tilled fields of long duration.

(3) Pembroke silt loam was sampled in Logan County in four fields, all located close together. The treatments were fescue sod, no tillage soybeans, conventional corn, and alfalfa recently planted on a soil where conventional tillage had long been practiced.

All soils were crushed by hand while still slightly moist and passed through a 2-mm sieve. Soil organic carbon was determined on each sample using a Leco CR-12 Carbon Analyzer. This is a dry combustion analysis for organic carbon. Duplicate samples were used for all determinations.

Maximum compactability (the maximum bulk density obtainable) was determined using the standard method (ASTM, 1991) with the following details. The mold or compaction chamber was filled and compacted in four layers, each layer receiving 25 blows from a standard falling hammer, for a total of 100 blows. Water content was varied in each case from the dry side of maximum bulk density to the wet side. A minimum of four and occasionally five individual moisture contents were used to approximate the curve.

After the weight of wet soil in the compaction chamber was determined, three soil moisture samples were taken so that soil dry weight and moisture content could be determined. These samples were weighed, dried in the oven at 110 "C for 24 hours, and weighed again. We observed practically no variation in soil water content between the three subsamples.

Maximum bulk density for each sample was estimated by extrapolating the "dry" leg and the "wet" leg of the samples to a point of intersection. This point also gives the moisture content at which the maximum bulk density is attained.

Results and Discussion

Figure 1 shows typical bulk density results for two samples over moisture ranges. As can be seen, maximum bulk densities can be estimated with considerable precision. In addition, as Kruger had indicated, the no-tillage sample shows lower bulk densities than does the conventional sample.

Table 1 shows the land use and management of sites sampled, the soil series, the maximum bulk density, and the per-

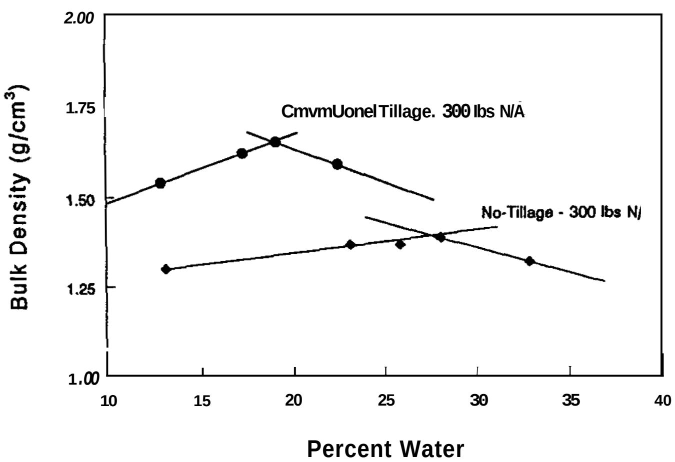

Figure 1. Bulk densities of a no-tillage and conventionally tilled Maury soil measured over a range of moisture.

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cent organic carbon. The range in both bulk density and organic carbon is relatively large, 1.4 to 1.8 g cm-3 and 1.0 to 3.5%, respectively. These data were separated by soil series and plotted in Figures 2, 3, and 4.

Figure 2 shows the bulk densities of samples of Maury silt loam plotted against percent organic carbon. The data gave an r^2 of 0.922 and a slope of -0.15qt/A. The latter indicates a change of 0.15 g cm-3 in bulk density for each one percent change in organic carbon. The samples do not appear to separate according to tillage itself but instead are closely related to organic carbon, which, in these experimental plots, is a result of 25 years of continuous treatment.

Figure 3 shows the relationship between maximum bulk density and organic carbon percentage for Lonewood soils. Again, regardless of treatment, the relationship is dominated by organic carbon content of the samples. The slope of the curve is –0.23 g cm^{-3} per percent organic carbon, somewhat steeper than that found in the Maury silt loam. The r^2 value is 0.92, about the same fit as in the case of the Maury samples.

Figure 4 shows the same relationship for the four Pembroke silt loam samples. The slope and intercept of the Pembroke and Maury soils were exactly equal, 1.88 and –0.15, respectively, indicating that texture and perhaps other soil characteristics are very similar in the two soils.

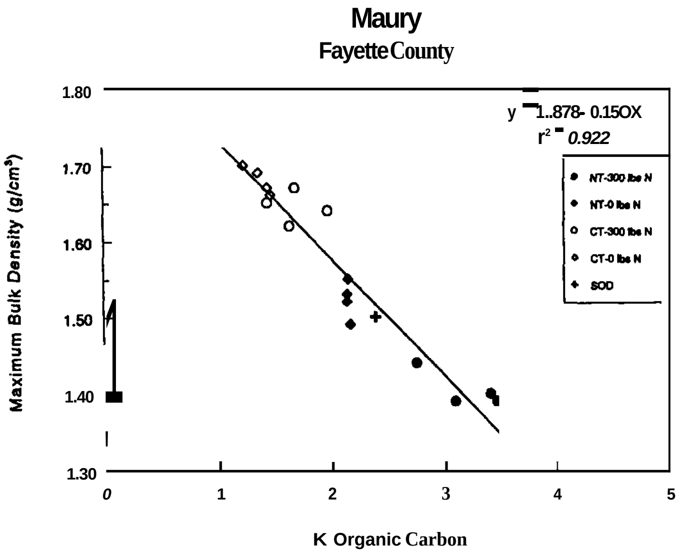

Figure 2. Relationship between maximum bulk density and organic carbon percentage for Maury soils.

Felton and Ali (1991) showed an effect of incorporating organic material (manure) on maximum bulk densities in subsoils of three Kentucky soils. Their results showed changes in bulk density of only between 0.056 and 0.077 g cm^{-3} per

Table 1. Soil, county, land use, maximum bulk density, and percent organic carbon in soils used in the experiments.

Soil	Land Use History		Maximum Bulk Density	% Organic Carbon
Maury silt loam (Fayette County)	**Conventional Corn, 25 years, 0 Nitrogen**	I	1.70	1.23
		11	1.69	1.36
		III	1.67	1.44
		IV	1.66	1.47
Maury	**Conventional Corn, 25 years, 300 lbs N/A**	I	1.65	1.44
		I1	1.67	1.69
		III	1.62	1.64
		IV	1.64	1.98
Maury	**No-tillage Corn, 25 years, 0 Nitrogen**	I	1.53	2.15
		I1	1.49	2.18
		111	1.55	2.16
		IV	1.52	2.15
Maury	**No-tillage Corn, 25 years, 300 lbs NIA**	I	1.40	3.41
		I1	1.39	3.47
		111	1.44	2.75
		IV	1.39	3.10
Maury Lonewood loam **(Russell County)**	**Permanent bluegrass-fescue** sod, **next to Expt.**		1S0	2.40
	Sod near fence line, Voils, **Hwy 379**		1.50	2.40
	No-tillage soybeans, Voils, Hwy 379		1.58	1.99
	No-tillage soybeans, Voils, **hog manure applied**		1.54	2.19
	No-tillage corn for silage, Halsell		1.70	1.33
	Conventional pepper field, Halsell		1.82	1.27
	No-tillage soybeans, Pyles		1.58	2.12
	No-tillage soybeans, half acre		1.65	1.69
	Conventional corn, John St.		1.77	1.10
Pembroke silt loam (Logan County)	**Permanent fescue sod, Hwy 663**		1.46	2.85
	Conventional Corn, Hwy 663		1.72	I.24
	New alfalfa—formerly conventionally tilled, Hwy 663		1.68	1.30
	No-tillage soybeans, Moore		1.65	1.45

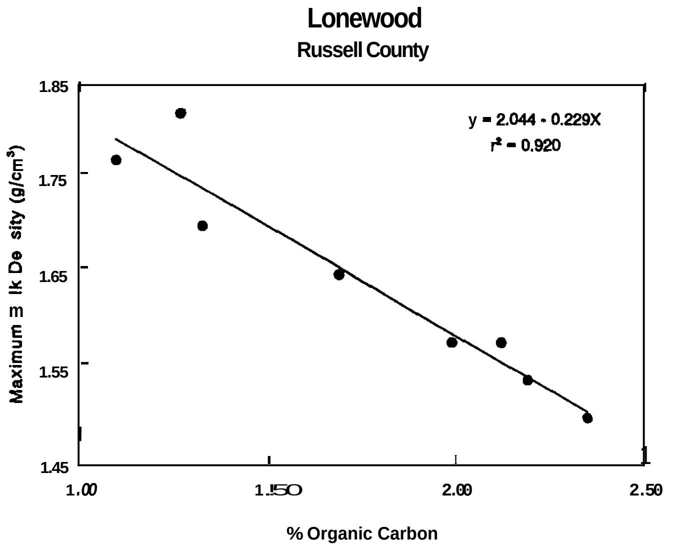

Figure 3. Relationship between maximum bulk density and organic carbon percentage for Lonewood soils.

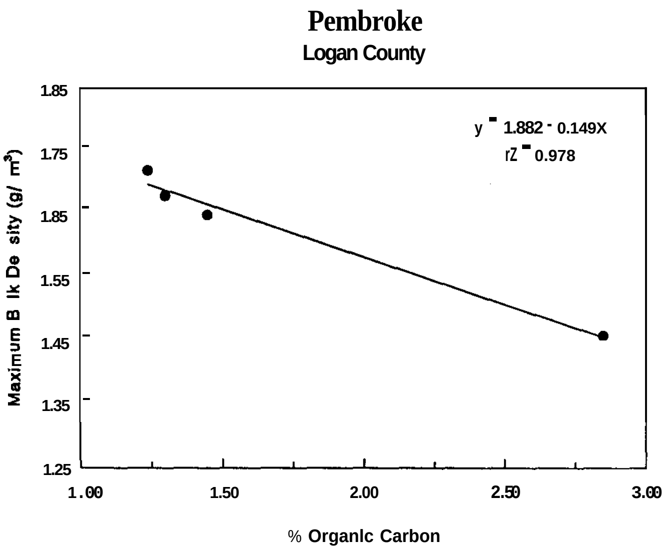

Figure 4. Relationship between maximum bulk density and organic carbon percentage for Pembroke soils.

percent organic carbon, whereas we observed 0.15 in Maury and Pembroke soils and 0.23 in the sandier Lonewood soil. However, both the composition of the organic material and its integration within the soil are different in our case. The organic matter is humus, and it has been thoroughly incorporated in the soil over a period of years. In the case of Felton and Ali, the manure was mixed just prior to the laboratory experiments.

This work has far-reaching, practical consequences. Of all the doubts about continuous no-tillage as a viable practice, the fear of compaction probably looms largest. This work shows clearly that with an adequate organic carbon content (probably around 2.5%) in the surface soil, the fear of compaction is essentially groundless. A prime role of organic matter, in addition to many other favorable effects, is resistance to compaction. Exactly how organic matter accomplishes this is open to question. We may speculate on *two* possible causes. First, organic matter aggregates the soil so that it resists compaction when it is compacted by hammering.

Second, organic matter binds the particles so that sorting does not occur during the compaction process.

Both of these mechanisms would result in less compaction.

Whatever the mechanisms, we have shown that one percent organic carbon lowers the maximum bulk density in three Kentucky soils by 0.15 g cm^{-3} to 0.23 g cm^{-3} which is a very significant effect. Together with the other favorable effects of organic matter on soil properties, this certainly suggests that the maintenance and increasing of organic matter contents in soils is a worthy goal. The use of no-tillage is a practical and efficient means to attain that goal.

Literature Cited

ASTM. 1991. Test method for laboratory comparison of soil using modified effort (56,000 ft-lbf/ft3 (2,700 k **N-m/m3)).** ASTM Designation: D 1557-91.

Felton, G.K., and M. Ali. 1992. Hydraulic parameter response to incorporated organic matter in the B-horizon. Transaction of the ASAE **35:1153-1160.**

Ismail, Isro, R.L. Blevins, and W.W. Frye. 1994. Long-term notillage effects on soil properties and continuous corn yields. Soil Sci. SOC. Am. J. 58:1193-198.

Conservation Tillage Systems for Corn Production on a Loessial Silt Loam and Alluvial Clay in Louisiana

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Introduction

Corn acreage has increased in recent years in Louisiana. Much of this is on mixed to heavy Mississippi River alluvial soils and to a lesser extent on loessial silt loams of the Macon Ridge. Each of these soil groups are unique in their physical and chemical characteristics and different management strategies may be required to produce optimal yield.

Research has indicated that corn performs best when planted early. Soil water within the rhizosphere may not be as plant available on clay as silt loam alluvial soils partly due to less efficient root development and physiology, making clays more drought prone. Thus, early planting dates on clay soils may be more critical than on the more coarse-textured soils. Additionally, planting in many years may be delayed because of poor seedbed conditions on clay soils, particularly if primary tillage operations are performed in early spring. Spring tillage typically produces cloddy seedbeds requiring rainfall or irrigation to produce optimal planting conditions.

According to Boquet and Coco (1993), one of the principal advantages of no-till systems is more timely planting, especially on the poorly drained, clayey soils. Herbek et al. (1986) found a trend for corn yield to increase as planting date increased from late April to mid-May for the no-till system on a poorly drained soil, while yield for the conventionally tilled plots decreased with delayed planting date.

In a Louisiana study, Hutchinson et al. (1994) found on the Macon Ridge only small differences in corn yield among conventional-till, reduced-till, and no-till treatments. Although limited tillage research on corn has been conducted in Louisiana, no-till or minimum-tillage production systems for cotton have shown promise when compared to the more traditional tillage practices on alluvial clays of the Mississippi River (Boquet and Coco, 1993; Crawford, 1992; Reynolds, 1990) and on the Macon Ridge (Hutchinson and Shelton, 1990). The inclusion of winter cover crops in combination with conservation tillage was found to be an important component of the systems.

The use of minimum-tillage systems may reduce soil erosion, especially on the sloping silt loams of the Macon Ridge (Hutchinson et al., 1991); increase soil organic matter (Boquet and Coco, 1993); reduce soil moisture evaporation (Wilhelm et al., 1986); and modify soil temperature (Wilhelm et al. 1986). The use of a leguminous cover crop, i.e. crimson clover, contributes biologically fixed N (Ebelhar et al., 1984), thus reducing need for application of N fertilizer and the potential of polluting ground water with nitrate-N.

Information is needed for corn production systems that will enhance profitability and protect the environment from unnecessary pollution of soil and water. Objectives of these experiments were to evaluate the influence of tillage systems, cover crops, and N rate on corn grain yield and yield components on two soil types.

Materials and Methods

Experiments were conducted in 1993 and 1994 to evaluate the effects of tillage systems, cover crops, and N rates on corn grown on Sharkey clay (very fine, montmorillonitic, nonacid, thermic Vertic Haplaquepts) at the Northeast Research Station, St. Joseph , LA, and on Gigger silt loam (fine silty, mixed, thermic Typic Fragiudalf) at Winnsboro, LA. Tillage treatments were conventional tillage (CT) and no-till (NT). Cover crop treatments were native vegetation, crimson clover ('Dixie' in 1993 and 'Tibbee' in 1994) and wheat ('Florida 303'). Nitrogen rates evaluated were 50, 100, 150, and 200 lb N/A.

At Winnsboro, the experimental design was a randomized complete block with a split-split plot arrangement of treatments. Tillage treatments were main plots, cover crops split plots, and N rates split-split plots. At St. Joseph, the experimental design was a randomized complete block with a split plot arrangement of treatments. Tillage treatments were main plots and cover crops and N rates were factorially arranged as split plots. In 1993, tillage treatments were not evaluated at St. Joseph (NT management was used). In that year, the experimental design was a randomized complete block with cover crops and N rates factorially arranged. Plots were four rows wide (40-inch row width) and ranged from 28 to 40 feet long.

Conventional-till consisted of double-disking, bedding, and a bed-smoothing operation just before planting. No-till consisted of no spring primary tillage operations. At Winnsboro,

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the last cultivation of cotton helped rebuild the bed and no fall tillage was performed. At St. Joseph, beds were rehipped and smoothed (rolled) for planting in the fall.

Cover crops (crimson clover and wheat) were hand broadcast at seeding rates of 25 lb/A for crimson clover and 120 lb/A for wheat. Planting dates for cover crops were between mid-October and early November. At Winnsboro, seeds were broadcast into standing cotton stalks. After seeding, cotton stalks were cut with a rotary mower. At St. Joseph, beds were smoothed (rolled) immediately after seeding the cover crops.

Cover crops did not establish as well in 1993 as in 1994. In 1993, one burndown was applied at St. Joseph (March 9) and two applications at Winnsboro (March 9 and April 22). For each application, except April 22 at Winnsboro, 1 lb ai/A of glyphosphate was used on wheat plots, and 0.6 lb ai/A of paraquat plus 0.25% surfactant were applied on crimson clover and native vegetation plots. For the April 22 application at Winnsboro, 1 lb ai/A of 2,4-D amine was applied on NT treatments. In 1994, two burndown applications of 0.6 lb ai/A of paraquat plus 0.25% surfactant were applied in early to late March across all cover crop treatments. A similar rate of paraquat was also applied with preemerge treatments at both locations.

Preemerge treatments consisted of labelled rates of alachlor or metolachlor and atrazine at each location. Postemerge applications were 0.75 oz/A of primisulfuron at St. Joseph in 1993; 1 lb ai/A of linuron plus 0.25% surfactant at Winnsboro in 1993; and 1.5 lb ai/A of linuron and 1 lb ailA of atrazine plus 0.25% surfactant at St. Joseph in 1994. Insecticide treatments were 1 lb ai/A of carburan applied in-furrow at St. Joseph in 1993, and 1 lb ai/A of terbufos applied in-furrow in all other tests. At Winnsboro in 1993,0.03lb ai/A of cypermethrin was applied (May 6) for a cutworm infestation in the NT treatments. All plots were cultivated once in 1993 and only the CT treatment at St. Joseph was cultivated (once) in 1994.

Corn ('Pioneer Brand 3165') was planted at about 26,000 seeds/A using a John Deere 7100 or 7300 planter. Ripple coulters, if needed, were mounted on the planter for no-till planting. Planting dates were April 13 at both locations in 1993 and April 8 at Winnsboro in 1994. At St.Joseph in 1994, planting dates were different for the tillage treatments due to inclement weather affecting the CT seedbed preparation. Planting dates were March 21 for NT and April 11 for CT.

Nitrogen treatments were broadcast at about the four-leaf growth stage. Nitrogen source was ammonium nitrate. Plant samples were taken at early-silk growth stage each year. Earleaf samples were collected in 1993 and whole plant samples were collected in 1994. Plant N concentrations were determined using Kjeldahl procedures.

Corn was harvested from two center rows of each four-row plot. Grain yields were adjusted to 15.5% grain moisture. Analyses of variance of yield data were conducted using the GLM procedures of SAS. The LSD (P=0.05) was calculated for mean separation.

Results

St. Joseph

Grain yields ranged from 34 to 86 bu/acre in 1993 (Table 1) and from 83 to 178 bu/acre in 1994 (Table 2). More timely rainfall probably accounted for the higher grain yields in 1994. There were no significant interactions among treatments for grain yield either year.

In 1994, the only year tillage treatments were evaluated at St. Joseph, grain yield did not differ between tillage treatments (Table 2). As a result of delayed seedbed preparation due to wet soil conditions, the CT treatment was planted ap-

Table 1. Influence of tillage, cover crop, and N rate on corn grain yield, plants per acre (PPA), ears per acre (EPA), kernel weight, and kernels per ear at St. Joseph in 1993.

Treatment	Grain yield	PPA	EPA	Kernel weight	Kernels
	bu/A			g/l00	nolear
Cover crop					
Native vegetation	62	21,022	20,204	25.3	302
Wheat	59	20,628	19,372	25.2	304
Crimson clover	74	21,371	20,519	25.1	357
LSD (0.05)	6	N.S.	639	N.S.	27
N rate, Ib/acre					
50	34	20,715	18,899	24.2	184
100	62	21,480	20,190	25.1	308
150	79	21,081	20,888	25.4	377
200	86	20,755	20,150	26.0	417
LSD (0.05)	7	N.S.	738	0.5	31

N.S. = nonsignificant at the 0.05 probability level.

Table 2. Influence of tillage, cover crop, and N rate on corn grain yield, plants per acre (PPA), ears per acre (EPA), kernel weight, and kernels per ear on Sharkey clay at St. Joseph in 1994.

Treatment	Grain vield	PPA	EPA	Kernel weight	Kernels
	bn/A			g/loo	nolear
Tillage'					
No-ti11	136	24,405	22,689	31.8	464
Conventional	140	27,190	25,982	30.7	439
LSD(O.05)	N.S.	1052	1363	N.S.	N.S.
Cover crops					
Native	155	27,021	25,581	31.6	485
Wheat	102	23,841	22,031	30.3	382
Crimson Clover	157	26,530	25,396	32.0	487
LSD(O.05)	7	742	630	0.6	28
N rate, Ib/acre					
50	83	25,537	23,692	28.9	305
100	130	25,809	24,194	30.2	447
150	162	25,803	24,459	32.5	516
200	178	26,040	24,997	33.5	538
LSD(O.05)	8	N.S.	727	0.7	32

N.S. = Nonsignificant at the 0.05 probability level.
'No-till and conventional planted on March 21 and April 11, 1994, respectively.

proximately 3 weeks later than the NT treatment. Although tillage treatments were confounded by planting date, the delayed planting resulting from seedbed preparation is considered part of the treatment effect. Planting dates for NT (March 21) and CT (April 11) were within the recommended planting window for north Louisiana (March 15 to April 15).

Much of the research data available in Louisiana on corn planting dates is for silty soils (Mascagni et al., 1994), with little information available for clay soils. The clayey soils tend to be more drought prone than the coarser-textured alluvial soils. Thus, early planting dates may be more critical on the clay soils.

Grain yields were influenced by cover crops each year. Highest grain yields followed crimson clover in 1993 (Table 1) and crimson clover and native vegetation in 1994 (Table 2). The lack of a significant cover crop x N rate interaction suggests that crimson clover did not contribute plant-available N during the growing season. Furthermore, percent N content of corn following crimson clover was similar to native vegetation each year (Table 5). Boquet and Coco (1993) concluded that a winter legume cover crop had several beneficial effects for cotton production on a Sharkey clay soil, including a rotational effect independent of the nutritional (N) aspect.

In 1994, corn growth was severely reduced by the wheat cover crop treatments regardless of tillage treatment. Grain yield following wheat was decreased about 35% compared to the other cover crops (Table 2). Although plant populations were decreased following wheat, this would not account for the large difference in grain yield among cover crop treatments. Grain yield response per unit of applied N was similar among treatments. This is best illustated by the similarity of responses among treatments (Figure 1). Both low seed weight and low number of kernels/ear contributed to the reduced grain yield following wheat.

Grain yield increased with application of N up to 200 lb/A,

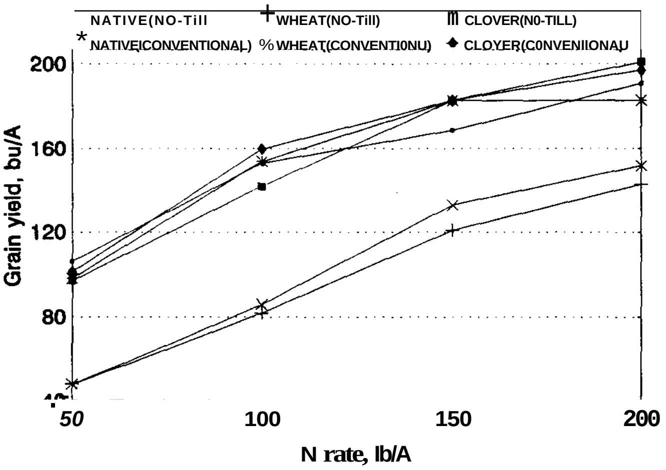

Figure 1. Influence of tillage, cover crop, and N rate on corn grain yield on Sharkey clay at St. Joseph in 1994.

regardless of cover crop treatment on this clay soil (Tables 1 and 2). Kernel weight and kernels/ear increased as N rate increased. Plant N content across N rates ranged from 1.71 to 2.42% in 1993 and 1.48 to 2.22% in 1994.

Winnsboro

Grain yields ranged from 104 to 123 bu/acre in 1993 (Table 3) and 104 to 141 bu/acre in 1994 (Table 4). Similar to St. Joseph, there were no significant interactions among treatments for grain yield.

Table 3. Influence of tillage, cover crop, and N rate on corn grain yield, plants per acre (PPA), ears per acre (EPA), kernel weight, and kernels per ear on Gigger silt loam at Winnsboro in 1993.

Treatment	Grain yield	PPA	EPA	Kernel weight	Kernels
	bu/A			g/100	no/ear
Tillage					
No-till	117	21,719	21,135	28.4	497
Conventional	115	24,201	23,773	26.4	468
LSD (0.05)	N.S.	476	606	0.8	N.S.
Cover crops					
Native	114	23,561	23,015	26.9	470
Wheat	117	23,196	22,491	27.5	481
Crimson Clover	118	22,123	21,856	27.9	496
LSD (0.05)	N.S.	851	667	0.5	N.S.
N rate, lb/acre					
50	104	22,623	21,999	27.3	441
100	117	23,762	23,090	27.6	469
150	121	22,834	22,518	27.3	503
200	123	22,621	22,209	21.4	517
LSD (0.05)	6	N.S.	N.S.	N.S.	23

N.S. =Nonsignificant at the 0.05 probability level.

Table 4. Influence of tillage, cover crop, and N rate on corn grain yield, plants per acre (PPA), ears per acre (EPA), kernel weight, and kernels per ear on Gigger silt loam at Winnsboro in 1994.

Treatment	Grain yield	PPA	EPA	Kernel weight	Kernels
	bu/A			g/100	no/ear
Tillage					
No-till	129	17,622	17,306	32.3	607
Conventional	128	21,153	19,892	31.8	537
LSD(O.05)	N.S.	1095	N.S.	N.S.	N.S.
Cover crops					
Native	127	19,607	19,084	32.6	536
Wheat	124	19,130	18,144	31.8	576
Crimson Clover	134	19,432	18,586	31.8	602
LSD(O.05)	6	N.S.	N.S.	N.S.	N.S.
N rate, lb/acre					
50	104	19,080	18,331	30.3	490
100	129	19,448	18,596	32.0	578
150	141	19,704	18,953	33.0	611
200	141	19,317	18,517	32.9	607
LSD(O.05)	10	**N.S.**	**N.S.**	1.5	N.S

N.S. = Nonsignificant at the 0.05 probability level.

There was no difference between tillage treatments for grain yield in either year (Tables 3 and 4). Plant populations (PPA) for NT were 10.3 and 16.7% lower than CT in 1993 and 1994, respectively. In 1993, there was a significant tillage x cover crop interaction (P=0.08). Corn stand following crimson clover in NT treatment was lower than the other two cover crops (20,351 versus 22,402 PPA), probably because of a cutworm infestation.

In 1994, cover crops significantly affected grain yield (Table 4). Grain yield following crimson clover was 10 bu/A higher than wheat and 7 bu/A higher than native vegetation. Plant N content was significantly higher following crimson clover than the other cover crops in 1994 (Table 5). However, similar to St. Joseph findings there was no significant cover crop x N rate interaction, suggesting that yield benefit from crimson clover may have been caused by some factor other than leguminous N.

On this nonirrigated loessial silt loam, optimal grain yield occurred between 100 and 150 lb N/A regardless of cover crop treatment (Tables 3 and 4). Increased kernels/ear in 1993 and increased kernel weight and kernels/ear in 1994 were the yield components contributing to the N rate yield response. Nitrogen content was increased from 2.96 to 3.12% in 1993 and 1.41 to 1.95% in 1994 by N application (Table 5).

Table 5. Influence of tillage, cover crop and N rate on corn plant N status at St. Joseph and Winnsboro in 1993 and 1994.

	1993'		1994	
Treatment	**St. Joseph**	**Winnsboro**	**St. Joseph**	**Winnsboro**
		% N		
Tillage				
No-Till	–	3.07	2.07	1.74
Conventional	–	3.14	1.74	1.69
LSD (0.05)	–	0.04	0.12	N.S.
Cover crops				
Native	2.13	3.08	1.91	1.67
Wheat	2.06	3.13	1.86	1.67
Crimson clover	2.17	3.11	1.95	1.80
LSD (0.05)	0.05	N.S.	N.S.	0.09
N rate, lb/acre				
50	1.71	2.96	1.48	1.41
100	2.07	3.04	1.88	1.67
150	2.29	3.22	2.05	1.82
200	2.42	3.21	2.22	1.95
LSD (0.05)	0.05	0.12	0.11	0.10

N.S. = Nonsignificant at the 0.05 probability level.
'Ear-leaf N in 1993 and whole plant N in 1994. Each year sampled at early silk.

Conclusions

Preliminary data suggest that minimum tillage systems may be equivalent to the traditional tillage systems on the loessial silt loam soils of the Macon Ridge. There was little agronomic benefit from cover crops in these studies. However, more research is needed to establish optimal minimum tillage production systems for corn, particularly on the clay soils.

Literature Cited

Boquet, D.J., and A.B. Coco. 1993. Cotton yield and growth responses to tillage and cover crops on Sharkey clay. p.100-105. In Proc. 1993 Southern Conservation Tillage Conference for Sustainable Agriculture, Monroe, LA 15-17 June 1993. Louisiana Agric. Exp. Stn. Baton Rouge, LA.

Crawford, S.H. 1992. Preplant weed control in conservation tillage systems for cotton. p. 139-140. *In* Proc. Beltwide Cotton Prod. Conf. 6-10 June, 1992. Nashville, TN. National Cotton Council of Amer. Memphis, TN.

Ebelhar, S.A., W.W. Frye, and R.L. Blevins. 1984. Nitrogen from legume cover crops for no-till corn. Agron. J. 76:51-55.

Herbek, J.H., L.W. Murdock, and R.L. Blevins. 1986. Tillage systems and date of planting effects on yield of corn on soils with restricted drainage. Agric. J. 78:824-826.

Hutchinson, R.L., R.E.A. Brown, B.R. Leonard, K.W. Paxton, and T.J. Riley. 1993. Alternative tillage systems and in-furrow insecticide for profitable corn production. Louisiana Agric. 37(2):23-25.

Hutchinson, R.L., R.C. Aycock, C.P. Boquet, S.M. Cruse, P.A. Miletello, C.L.Pinne1-Alison, R.L. Rogers, and W.W. Russell. 1991. An evaluation of conservation tillage systems for cotton on the Macon Ridge. Louisiana Cooperative Ext. Serv. Pub. 2460.

Hutchinson, R.L., and W.L. Shelton. 1990. Alternative tillage systems and cover crops for cotton production on the Macon Ridge. Louisiana Agric. 33(4):6-8.

Reynolds, D. 1990. Evaluation of burndown and residual herbicides for soybeans planted into a stale seedbed. p. 341-347. *In* Northeast Res. Stn. Ann. Prog. Rep. Louisiana Agric. Exp. Stn. Baton Rouge, LA.

Wilhelm, W.W., J.W. Doran, and J.F. Power. 1986. Corn and sorghum yield response to crop residue management under no-tillage production systems. Agron. J. 78:184-189.

Influence of Tillage and Wheat Cover Crop on Herbicide Inputs in Rice *(Oryza sativa)*

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Abstract

Interest in producing rice under reduced-tillage systems has increased in the southern United States. Additionally, the extensive use of pesticides has been scrutinized and has resulted in a search for management practices that reduce pesticide inputs through the use of cultural practices and biological control mechanisms. Development of effective and cost-efficient weed management strategies will continue to be critical regardless of the control tactics involved. Research was conducted at the Northeast Research Station located near St. Joseph, LA, and at the Rice Research Station located near Crowley, LA, to evaluate the effects of tillage, a wheat cover crop, and in-season herbicide inputs on weed control and rice yields in both dry- and water-seeded systems. Barnyardgrass *(Echinochloa crusgalli)* and purple ammania *(Ammania coccinea)* were the predominant weed species in the dry- and water-seeded systems, respectively. A wheat cover crop suppressed barnyardgrass and purple ammania relative to conventional tillage and stale seedbed systems and showed potential for reducing in-season herbicide inputs. Rice yields generally increased as the level of in-season herbicide input was increased. Yields in conventional tillage and stale seedbed systems were similar.

Introduction

Concern about environmental quality and food quality issues has led to increased emphasis on developing alternative production systems which employ cultural practices that minimize surface and ground water pollution and reduce herbicide inputs (Feagly et al., 1992). Success with alternative production systems, especially in the major agronomic crops, has been somewhat erratic. A need for further evaluation of alternative cropping systems and pest management strategies is needed to develop both cost efficient and profitable production systems with minimal environmental impact.

Rice is traditionally grown under conventional-tillage systems with heavy reliance on herbicides for weed control. However, rice can be successfully produced in reduced-tillage systems (Bollich and Sanders, 1993). Research in other crops indicates that cover crops can suppress weeds, and, in some instances, may reduce the need for some herbicide inputs (Worsham, 1991). Limited data exist evaluating the interactions of tillage systems, cover crops, and herbicide inputs in rice. Therefore, experiments were conducted to evaluate weed control and rice yield with various tillage/cover crop systems with varying levels of in-season herbicides.

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Materials and Methods

Field experiments were conducted at the Northeast Research Station located near St. Joseph, LA (Sharkey silty clay soil) and at the Rice Research Station located near Crowley, LA (Crowley silt loam soil) to evaluate interactions among tillage practices, cover crop, and in-season herbicide inputs with respect to weed control and rice grain yield. Treatment factors within both dry- and water-seeded systems included three levels of tillage/cover crops [conventional (CT), stale seedbed (SB), and no-till with a wheat cover crop (WC)]. The entire test area was tilled in the fall and leveled. Wheat was established by planting 100 lb seed/A using a grain drill with 8-inch row spacings.

Winter and summer weeds and the wheat cover crop were controlled prior to rice emergence in the SB and WC systems with combinations of glyphosate, the amine formulation of 2,4-D, and paraquat. Glyphosate + 2,4-D amine, each at 1.0 lb ai/A, were applied approximately one month prior to planting in the SB system at both locations and in the WC system at Crowley. Glyphosate at 1.0 lb/A was applied in the WC system at St. Joseph. Paraquat was applied at planting in the SB system at both locations.

In the CT system, plots were plowed with a field cultivator two to three times prior to planting. Within each of these systems, four levels of in-season herbicide input included (1) no herbicides, (2) propanil early postemergence (POST), (3) the commercial mixture of propanil plus molinate early POST (dry and water-seeded) followed by propanil (dry-seeded) or molinate (water-seeded) applied late POST, and (4) thiobencarb preplant (water-seeded) or thiobencarb plus quinclorac delayed preemergence (dry-seeded), each of which were followed by propanil plus bentazon POST. These four herbicide programs will be referred to as no in-season herbicides and low, moderate, and high input herbicide programs, respectively. Propanil, propanil + molinate, bentazon, thiobencarb, quinclorac, and molinate were applied at 4.0, 4.5, 1.0, 3.0, 0.5, and 3.0 lb ai/A, respectively.

Seeding rates for 'Cypress' rice were 100 and 150 lb/A in the dry- and water-seeded systems, respectively. At Crowley in both seeding methods, 90 pounds actual nitrogen (N/A) were applied preflood followed by 65 lb N/A at midseason. At St. Joseph, 135 lb N/A were applied preflood in the dry-seeded system. In the water-seeded system, and 90 lb N/A were applied preplant followed by 65 lb N/A at midseason. An additional 35 lb N/A were applied following the midseason application in the WC system for both seeding methods. Rice foliage in this system was showing visual indications of N stress.

Visual estimates of percent weed control were recorded at planting, at permanent flood establishment (dry seeded) or when rice was drained for the first N application (water seeded), at mid season, and at harvest. A scale from 0 to 100% was used in making the visual estimates where O=no control and 100=complete control. Plots were machine-harvested when rice grain moisture was between 16 and 20%. Data were subjected to analysis of variance and means for individual locations were separated with Fisher's Protected LSD test at $P < 0.05$.

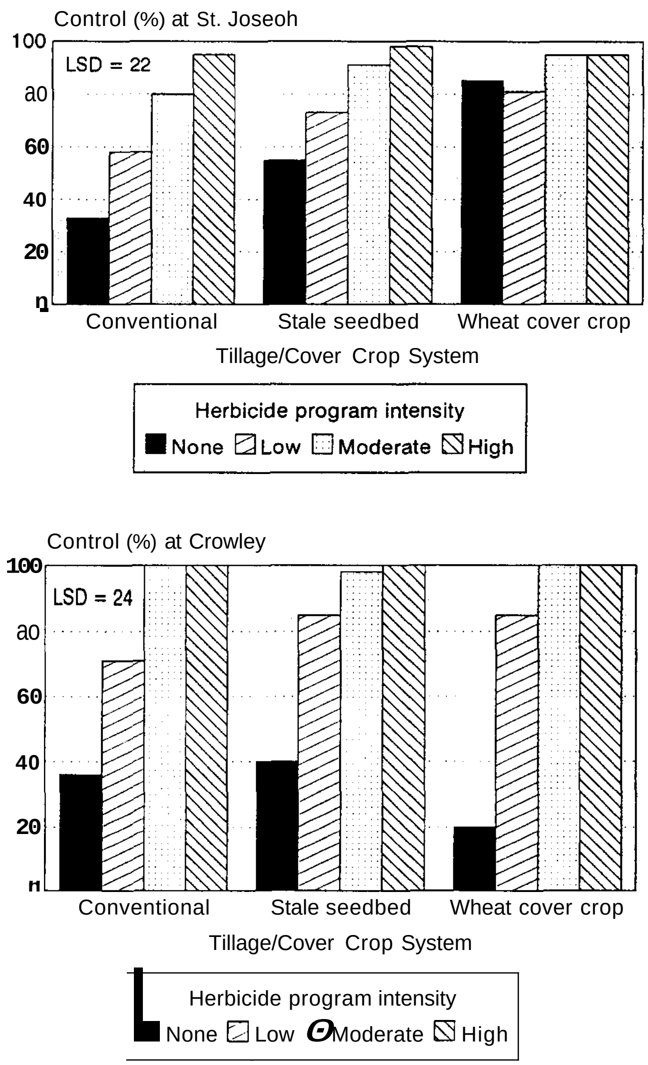


Figure 1. Barnyardgrass control with herbicide programs and tillage/cover crop systems in dry-seeded rice production.

Results and Discussion

Dry-seeded Production

Greater season-long barnyardgrass control was noted in the WC system compared to the SB and CT systems at St. Joseph when in-season herbicides were not applied (Figure 1). Less control was observed in the CT system compared to the SB system. In contrast, barnyardgrass control in the WC system at Crowley was lower than in the CT and SB systems. At St. Joseph in the CT system, barnyardgrass control with the low, moderate, and high input herbicide programs was 57, 80, and 95%, respectively. In the SB and WC systems, control with the low, moderate, and high input herbicide programs was 73, 91, and 98%, respectively, and 80, 95, and 95%, respectively. At Crowley, the low input herbicide program in the CT, SB, and WC systems provided 71, 84, and 84% control, respectively. At both locations, control with the moderate and high input systems was similar regardless of the tillage/cover crop system.

At St. Joseph, rice yields were greater when in-season herbicides were applied in the CT and SB systems (Figure 2). A trend for increased yield was noted as the intensity of the herbicide program increased. When in-season herbicides were not applied, yields with the SB and WC systems exceeded that with the CT system. No differences were noted among the herbicide programs in the WC system. At Crowley, yields in all tillage/cover crop systems generally increased when in-season herbicides were applied. Few differences in yield were noted when the intensity of the herbicide program was increased.

Water-seeded Production

At St. Joseph, purple ammania control in the CT, SB, and WC systems was 50, 2, and 65%, respectively, without in-season herbicides (Figure 3). When in-season herbicides were applied, control increased regardless of the tillage/cover crop system. At Crowley, control in the SB and WC systems exceeded that with the CT system when herbicides were not applied. The high intensity herbicide program, which contained thiobencarb, was needed to obtain maximum control. Thiobencarb is used routinely in water-seeded rice to control aquatic weeds such as purple ammania and duck salad *(Heteranthera limosa)*.

Few differences were noted among yields at St. Joseph regardless of the tillagekover crop system (Figure 4). At Crowley, the high intensity program resulted in greater yields than the other herbicide programs in the CT system. In contrast, yields were similar in the SB and WC systems regardless of the herbicide program.

Results from these studies indicate that tillage and cover crops can influence weed population dynamics and, *to* some degree, the intensity of herbicide programs needed to control weeds. In the dry-seeded system, barnyardgrass populations at St. Joseph were higher in the CT system compared with the SB and WC systems. Lack of soil disturbance in the SB and WC systems may have reduced barnyardgrass emergence by preventing additional seeds from being brought *to* the soil surface. Additionally, the WC system may also have reduced populations through the release of allelochemicals or shade. However, determining the mechanism of barnyardgrass suppression was beyond the scope of these experiments. At Crowley, fewer differences in barnyardgrass control were noted among the tillagekover crop systems.

Reasons for the differences observed between the two locations are not clear. Higher wheat populations at St. Joseph may have contributed to greater barnyardgrass suppression compared with that at Crowley, where wheat populations were lower. Soil properties (silty clay soil versus silt loam soil) also may have contributed to the observed differences between locations. Additionally, earlier rice planting at Crowley compared with St. Joseph may have contributed to differences in weed pressure and subsequent response to herbicides and tillagekover crop systems.

Differences in purple ammania infestations between the two locations also were noted. At St. Joseph, the CT and WC

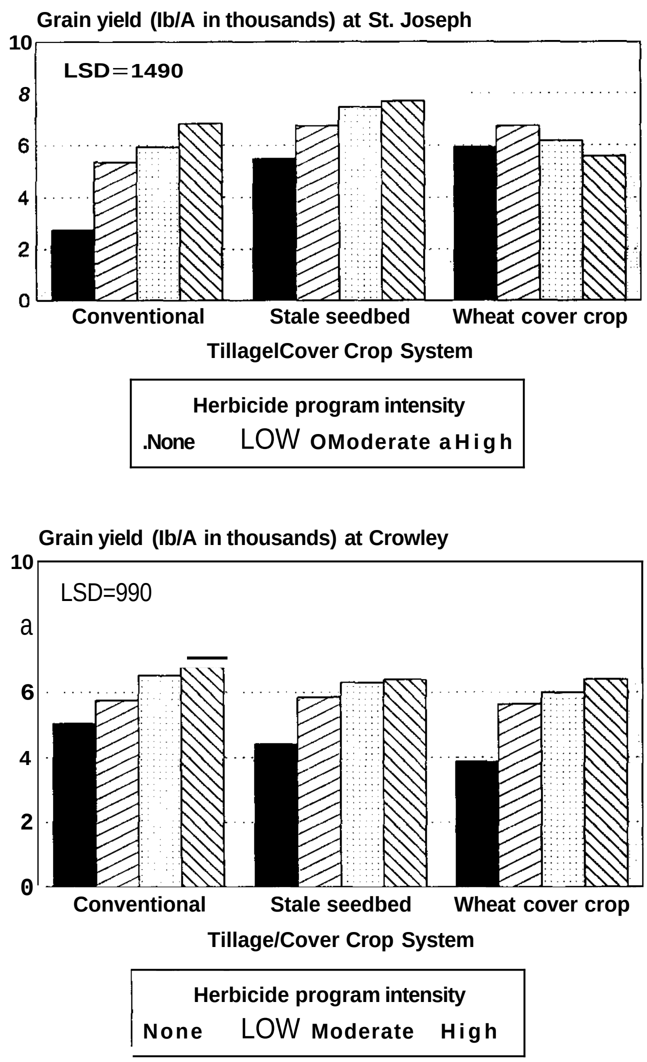


Figure 2. Rice grain yield with herbicide programs and tillage/cover crop systems in dry-seeded rice production.

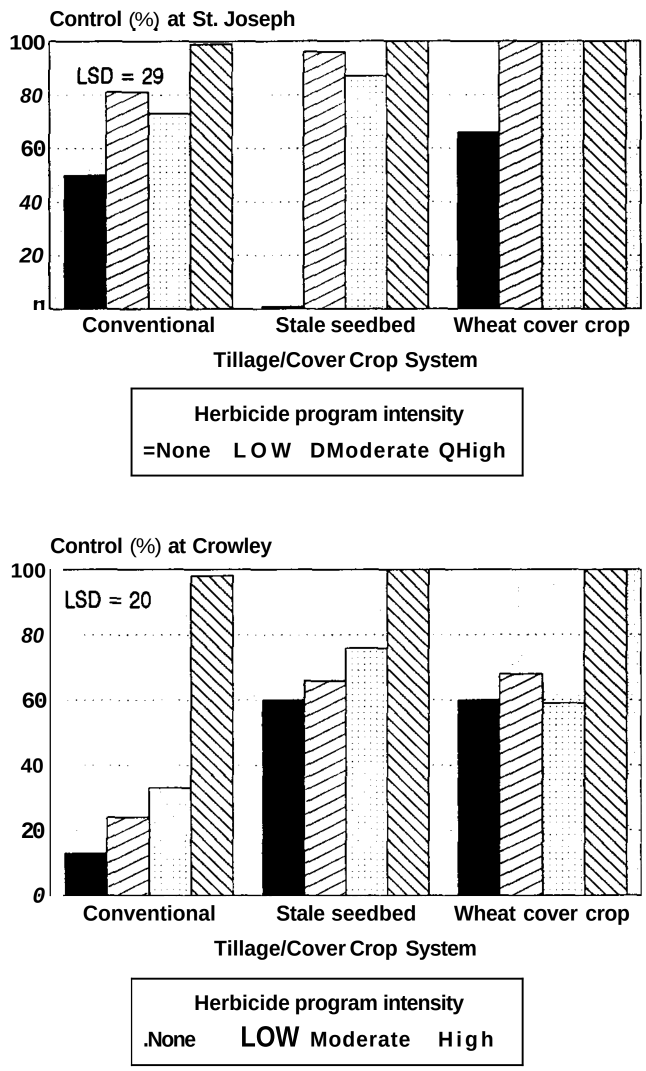


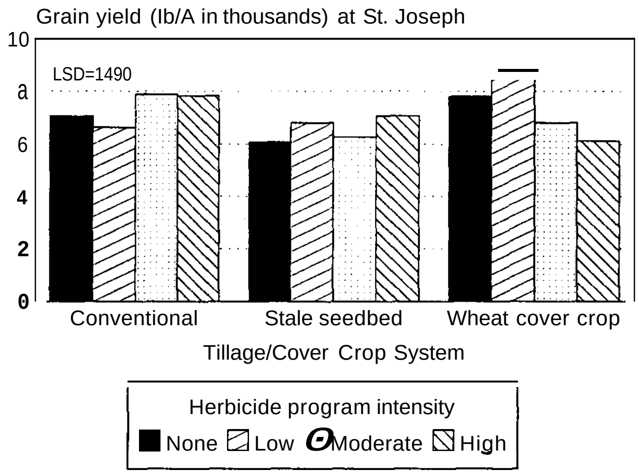
Figure 3. Purple ammania control with herbicide programs and tillagekover crop systems in water-seeded rice production.

systems provided similar control, and control with these systems exceeded that with the SB system. Differences in control may have been related to suppression of purple ammania by the WC system or tillage in the CT system compared with the SB system. Lack of tillage or cover crop suppression may have contributed to the lack of control in the SB system.

Differences in yield did not always reflect differences in weed control, and this was especially true in the water-seeded system. Increasing the intensity of the herbicide program generally resulted in increased yield in the dry-seeded system.

At St. Joseph, rice yields in the dry- and water-seeded systems were somewhat erratic in the WC system. Rice stands were reduced in the WC system relative to the other two tillage/cover systems (data not presented). Excessive decaying residues may have contributed to the difficulty in establishing stands in this system. Other research has shown adequate rice stands can be difficult to obtain in no-till production systems where heavy plant residues are present (Bollich, 1992). Factors suppressing barnyardgrass and purple ammania may also have affected the rice seedlings in the WC system. In addition, N immobilization by the wheat residue may have restricted early-seasan growth.

Collectively, these data suggest that rice produced in reduced-tillage systems can provide yields similar to those in conventional-tillagesystems in both dry- and water-seeded production. These data also indicate that changes in tillage and the use of cover crops can influence weed population dynamics and herbicide programs needed for control. Additional research is needed to further determine the advantages and disadvantages of tillage and cultural practices as related to weed management strategies with emphasis on weed control, yields, and economic returns.



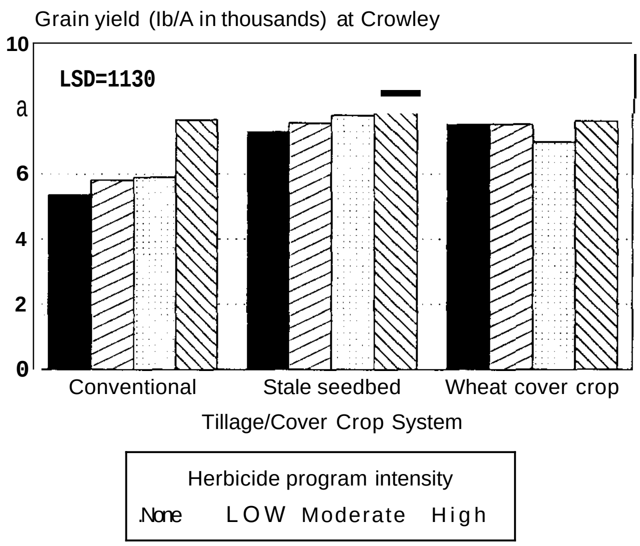


Figure 4. Rice grain yield with herbicide programs and tillage/cover crop systems in water-seeded rice production.

Acknowledgments

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Literature Cited

1. Bollich, P.K. 1992. Conservation tillage practices for water-seeded rice. Proc. Southern Conservation Tillage Conf., Special Pub. 92-01, pp. 53-55.
2. Bollich, P.K., and D.E. Sanders. 1993. Non-selective and residual herbicide tank mixes in no-till rice. Proc. Southern Conservation Tillage Conf., Louisiana Agric. Exp. Stn., MS. 93-86-7122, pp. 21-25.
3. Feagley, S.E., G.C. Sigua, R.L. Bengston, P.K. Bollich, and S.D. Linscombe. 1992. Effects of different management practices on surface water quality from rice fields in south Louisiana. J. Plant Nutrition, 15(8):305-321.
4. Worsham, A.D. 1991. Allelopathic cover crops to reduce herbicide inputs. Proc. Southern Weed Sci. Soc. 44:58-69.

Sweetpotato Response to Cover Crops and Conservation Tillage

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Introduction

Corn *(Zea mays* L.) was one of the first crops to be grown successfully with no-tillage (NT). As technology advanced and new herbicides were developed, other crops such as soybean *[Glycine max* (L.) Merr.] and sorghum *[Sorghum bicolor* (L.) Moench] have been extensively planted using NT. Once thought that intensive tillage was required for maximum yields, cotton *(Gossypium hirsutum* L.) has now been shown to respond favorably to NT (Bloodworth and Johnson, 1992).

Sweetpotato *[Zpomoeabatatas* (L.) Lam.] is considered to be a highly erodible crop. Fields are disked and hipped multiple times in order to prepare the seedbed. Soil disturbance at harvest decreases the amount of crop residue remaining on the soil surface. Soil loss from sweetpotato production has been estimated to be up to 22 tons/acre (USDA-NRCS, Jackson, MS).

With escalating production costs and the need for soil conservation, farmers are interested in the effects of NT and cover crops on alternative crops such as sweetpotato. This study was initiated to determine how NT and cover crops affected sweetpotato growth and development.

Materials and Methods

This study was conducted at the Jamie L. Whitten Plant Materials Center near Coffeeville, MS, from 1991 to 1994. Plots were four rows (40-inch row spacing) 25 feet in length. Soil types were Oaklimeter silt loam (Coarse-silty, mixed, thermic Fluva quentic Dystrochrepts) in 1991-1992, and Grenada silt loam (Fine-silty, mixed, thermic Glossic Fragiudalfs) in 1992-1994. Plots were rotated to a different field each year. Experimental design was a randomized complete block with two or four replications. Analysis of variance was used to determine if significant differences occurred (P ≥ 0.05). Duncan's Multiple Range Test (DMRT) was used to separate means that did differ significantly (Steel and Torrie, 1960).

Seedbeds for the cover crops were prepared by disking twice (2X), hipping 2X, and lightly harrowing. P and K were broadcast-applied according to soil test results for sweetpotato. Cover crops were broadcast planted on Nov. 6, 1991 at 20, 30, 90, and 90 lb/A for crimson clover *(Trifolium incarnatum* L. var. 'Tibbee'), hairy vetch *(Vicia villosa* L.), rye *(Secale cereale* L. var. 'Elbon'), and wheat *(Triticum aestivum* L.), respectively. Diclofop methyl (Hoelon@) was applied at 0.75 lb ai/A on Dec. 17, 1991 to all plots to control ryegrass *(Lolium multiflorum* Lam.). Seeding rates were reduced to 15, 20, 60, and 60 lb/A for crimson clover, hairy vetch, rye, and wheat, respectively, in 1992 and 1993. Planting dates were Oct. 8, 1992 and Oct. 28, 1993. Legume seeds were inoculated with the proper rhizobia prior to planting each year. Disking 2X, hipping, and harrowing in the spring served as a conventional tillage (CT) check. Canopy cover was determined by visually estimating the'amount of cover in each plot. Dry matter (DM) yields were determined by hand harvesting 4 square feet in each plot prior to cover crop termination. Native cool season weeds varied from year to year but mainly consisted of henbit *(Lamium amplexicaule* L.), chickweed *[Stellaria media* (L.) Cyrillo], and cutleaf eveningprimrose *(Oenothera laciniata* Hill). Cover crops were chemically killed using glyphosate (Roundup@) applied at 2.0 lb ai/acre on approximately April 15 of each year.

Prior to transplanting, glyphosate was applied at 1.0 lb ai/A to control surviving weeds. On approximately June 5 of each year, slips of 'Jewel' were transplanted at an in-row spacing of 16 inches. Ammonium nitrate was broadcast applied at 150 lb/A to rye, wheat, native cover, and CT plots at planting. Crimson clover plots received 60 lb/A ammonium nitrate. Sethoxydim (Poast@) at 0.19 lb ai/A was applied postemergence to control grass weeds. Plots were hand-weeded each year as needed to control broadleaf weeds. Conventionally tilled plots were cultivated twice each year. Potato yields were determined by hand harvesting a middle row in each plot, air drying to an uniform moisture content, weighing, and grading. Harvest dates were Sept. 15, 1992, Sept. 28, 1993, and Oct. 27, 1994. Yield data were not analyzed because of low yields because of excessive competition from yellow nutsedge ***(Cyperus esculentus*** L.) and severe browsing by deer in 1994.

Results and Discussion

Because of excessive soil moisture from January to early

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March, canopy cover ratings and dry matter yields were not recorded in 1992. However, canopy cover was adequate by mid-April (data not presented). In 1993, canopy cover of native weeds was significantly higher in March and April than cover from rye or the legumes (Table 1). Rye and wheat increased canopy cover during February and March of 1994 more than the other species. Bloodworth et al. (1993) reported that soil loss could be reduced up to 75% when cover crops were planted with cotton. In their study, soil loss was greater with native cover due to variation in volunteer stands of cool season weeds.

Though not evaluated in this study, surface residues have been shown to have beneficial effects other than reducing soil loss. Bond and Willis (1971) and Moody et al. (1963) reported higher soil moisture levels associated with high residue levels. Moody et al. also reported lower soil temperatures and a higher rate of growth and yield for corn when planted into mulched plots. In 1994 of this study, crimson clover and hairy vetch produced significantly higher dry matter yields than rye or native weeds (Table 2). High legume DM yields could decrease the need for commercial N fertilizers in sweetpotato production.

No unusual problems occurred at planting or during the potato growing seasons except in 1994. Soil moisture levels at planting were extremely low in all plots, which resulted in the transplanter's closing wheels leaving the roots of many slips exposed. We did notice that the wheat and rye plots held soil moisture better in 1994 than the other species, resulting in better planter operations. However, sweetpotato stands in the cover crop plots were comparable to those in the CT plots where the closing wheels worked as they should. No modification had been done to the transplanter to adapt it to NT use.

No significant differences were found between cover crops and tillage for sweetpotato yields (50 pounds per bushel) in any year (Table 3). In a North Carolina study, NT potatoes (species not specified) with cover crops produced yields equal to or higher than the state average (Hoyt, 1984). Buxton (1981) reported higher infiltration rates in potato (species not specified) fields where high amounts of residue from cereal grains had been produced. He stated that moderate compaction in the plow layer affected yield more than quality.

Table 1. Cover crop canopy cover, by dates, 1993-1994.

	Canopy cover					
	1993			1994		
Cover croD	2/02	3/01	4/06	2/01	3/11	4/08
	%					
Crimson clover	19'	8cd	35b	21b	25b	73
Hairy vetch	22	7d	40b	6c	8c	65
RYe	26	13bc	32b	49a	55a	83
Wheat	21	15ab	45b	47a	65a	79
Native weeds	20	20a	60a	5c	26b	84

[1] Means within a column not followed by a common letter are significantly different as determined by DMRT (P>0.05).

Table 2. Cover crop dry matter yield, 1993-1994.

	DM yield	
Cover crop	1993	1994
	lb/acre	
Crimson clover	3,338[1]	477a
Hairy vetch	4,079	422a
Rye	3,867	2602b
Wheat	3,892	3,490ab
Native weeds	2,900	2,248b

[1] Means within **a column** not followed by a common letter are significantly different as determined by DMRT (P>O.O5).

Table 3. Sweetpotato yields by cover crop and tillage, 1992-1993.

Cover crop/ tillage system	1992			1993		
	Canner	#1	Total	Canner	#1	Total
	bu/acre			bu/acre		
Crimson clover	223[1]	47	270	69	74	143
Hairy vetch	260	57	317	66	107	173
RYe	244	93	337	72	75	147
Wheat	195	58	253	74	56	130
Native cover	206	36	242	68	92	170
Conv. till	244	46	290	55	74	129

[1] Means within a column not followed by a common letter **are** significantly different as determined by DMRT (P>0.05).

Conclusions

This study was to determine if sweetpotato could be successfully grown in a NT system and how cover crops affected plant growth. Results showed that NT sweetpotato produced similiar yields and quality to CT sweetpotato. Cover crops did not influence yield and quality.

Producers facing narrow profit margins may not use cover crops when deliberating how only yield will be affected. However, cover crops' ability to decrease soil erosion, conserve soil moisture, and decrease weed competition should be considered.

Future research should be focused on how much tillage is necessary to maintain high sweetpotato yields, N fertilizer requirement of sweetpotato following legume cover crops, new transplanter designs, and the effects of herbicides used in sweetpotato production on cover crops.

Note: Mention of a trademark or proprietary product does not imply endorsement by the USDA-NRCS.

Literature Cited

Bloodworth, L.H., and J.R. Johnson. 1992. Cotton response to cover crops and tillage in the Brown Loam of Mississippi. p. 42-45. *In* M.D. Mullen and B.N. Duck (ed.) Proc. Southern Conserv. Tillage Conf. 21-23 July 1992, Jackson, TN.

Bloodworth, L.H., J.R. Johnson, and J.A. Parkman. 1993. Cover crops and tillage effects on cotton. Proc. Int. Erosion Control Assoc. 24:215-219.

Bond, J.J., and W.O. Willis. 1971. Soil water evaporation: Long-term drying as influenced by surface residue and evaporation potential. Soil Sci. SOC.Amer. Proc. 35:984-987.

Buxton, D.R. 1981. Tillage and cultural management for irrigated potato production. p. 210. *In* Agronomy abstracts. ASA, Madison, WI.

Hoyt, G.D. 1984. Cover crops for no-till vegetable and tobacco production. p. 250. *In* Agronomy abstracts. ASA, Madison, WI.

Moody, J.E., J.N. Jones, Jr., and J.H. Lillard. 1963. Influence of straw mulch on soil moisture, soil temperature and the growth of corn. Soil Sci. SOC. Amer. Proc. 27:700-703.

Steel, R.G.D., and J.H. Tome. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc., New York. 481 p.

Conservation Tillage Effects on Productivity in the Blackland Prairie

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Introduction

The 1985 and 1990 Food Security Act resulted in a renewed interest in conservation tillage, especially in the Blackland Prairie. The soils of this region are predominantly heavy, expanding clays and are highly erodible when tilled. They are underlined by soft limestone or chalk as the main soil-forming material. This formation, coupled with a relatively high cropping intensity, causes the land resource region to be one of the nation's most susceptible to productivity losses from soil erosion (USDA, 1989; U.S. Army Corps of Engineers, USDA-SCS, 1990). Research (Hairston et al., 1984; Hairston et al., 1987) in the Blackland Prairie has shown that a positive correlation existed for higher yields on soils with a greater soil depth. Continued loss of topsoil to erosion will eventually expose the unproductive chalk subsoil and render this region unsuitable for row crops.

Appropriate use of conservation tillage, including stale seedbed systems (ridge-tillage and no-tillage) and rotation systems, have the potential to be effective practices in minimizing production costs, enhancing productivity, and meeting conservation co mpliance. The objectives of this study were to evaluate crop yield response to selected tillage and crop rotation/tillage systems in the Blackland Prairie Region.

Materials and Methods

Studies were initiated in the fall of 1991 at the Mississippi Agricultural and Forestry Experiment Station Prairie Research Unit, Prairie, MS, and the Northeast Mississippi Branch Experiment Station, Verona. The Prairie site was a Vaiden silty clay (very-fine, montmorillonitic, thermic, Vertic Hapladalfs) generally acidic topsoil and with a 1 to 2% slope. The Verona site was a Leeper silty clay (fine, montmorillonitic, nonacid, thermic, Vertic Haplaquepts) with alkaline top-soil and 0 to 0.5% slope. The experimental design was a randomized complete block design with four replications. Plot sizes were 20 feet x 60 feet. Annual surface broadcast fertilizer applications of P20, and K20 and nitrogen for corn and wheat were made according to soil test recommendations.

The following continuous cropping tillage treatments were evaluated on both sites: (1) no-tillage (NT) corn; (2) ridge-tillage (RT1) corn, planted no-till and cultivated once with a high-clearance cultivator equipped with ridgers; (3) turf aerator (TA) corn, with turf aerator knives operated one month prior to planting at 10" angle from vertical and at a 4- to 6-inch depth on the Prairie site; (4) conventional raised-bed tillage (CTB) corn chiseled, disked, bedded, do-alled before planting, and cultivated once; (5) NT soybean; (6) ridge-tillage (RT2) soybeans planted no-till and cultivated twice with a high-clearance cultivator equipped with ridgers; (7) TA soybeans; and (8) conventional smooth seedbed tillage (CT) soybeans chiseled, disked, do-alled before planting, and cultivated twice during the growing season.

The following tillage/crop rotation treatments were evaluated on both sites: (1) RT1 corn followed by RT2 soybeans; (2) RT2 soybeans followed by RT1 corn; (3) NT corn followed by minimum tillage MT wheat (disked twice after corn harvest and do-alled before planting wheat) with NT doublecrop soybeans; (4) MT wheat followed by NT doublecropped soybeans followed by NT corn; (5) NT corn followed by MT bed wheat and NT doublecrop soybeans (Verona site); (6) MT bed wheat with NT doublecrop soybeans followed by NT corn (Verona site); (7) fall paratill bed (FPTB) soybeans followed by FPTB corn; and (8) FPTB corn followed by FPTB soybeans.

Corn plots were planted in 30-inch rows with 1.5 seeds/foot of row. Burndown and preemergence herbicides were applied to RT1, TA, and NT corn. Preemergence herbicides were applied to CTB corn plots. A post-directed herbicide was applied broadcast to N T and TA, and in a 15-inch band to RT1 corn. Nitrogen (N) as ammonium nitrate was applied broadcast over the top of all corn plots at 160 lb N/A (split application).

The herbicide 2,4-D was applied as an early (mid-February to mid-March) spring broadleaf weed control method on all monocrop soybean stale seedbed and wheat-doublecrop soybean treatments. Two weeks prior to planting soybeans, a burndown herbicide was applied to NT, TA, and RT2 soybean plots. Soybeans were planted in 30-inch rows with 9

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seeds/ft of row in May-June on monocrop treatments and in June on doublecrop treatments. A preemergence herbicide was applied to all monocrop soybean plots. Soybean weed control during the cropping season involved the use of broadcast over-the-top postemergence herbicides and/or post-directed herbicides applied on TA and NT treatments. Postemergence over the top and/or post-directed herbicides in 15-inch band with two cultivations were applied to RT2 and CT soybean treatments.

The center 6-foot wide swath of wheat was harvested for grain yield in both studies. The center two rows of corn and soybean plots, in both studies, were harvested for grain yield. Soybean and corn yield were adjusted to bushels per acre at 13.5 and 15.5% seed moisture, respectively. Data were subjected to statistical analysis (SAS, Cary, NC, 1991) and means were separated by Least Significant Differences (LSD) at the 0.05 probability level.

Results and Discussion

The first year (1992) was the establishment year; therefore, the data being reported for both locations are for 1993 and 1994. Rainfall for the 1993-1994 growing season of May-October ranged from 19 to 40 inches (Table 1). Rainfall for 1993 growing season ranged from normal for Prairie to above normal for Verona. The 1994 growing season rainfall was above normal at both sites, ranging from 150% to 170% of normal. Ample rainfall resulted in good corn and soybean yield at both locations.

Wheat

Wheat yields for 1993-1994 are presented in Table 2. A late spring freeze in 1993 resulted in cold injury to seed heads and low yields on both sites. Yields for 1994 were higher on the Vaiden soil than the Leeper soil, possibly because of less surface drainage on the Leeper than Vaiden site.

Corn

Both Leeper and Vaiden silty clay corn yields for 1993-1994 are presented in Table 3. The Vaiden soil in 1993 for raised-bed systems of continuous CTB and RTl corn, and rotation of RT2 soybeans followed by RTl corn showed no yield difference. The flat systems of continuous TA and NT corn and a rotation of MT wheat NT doublecropped soybeans followed by NT corn, however, produced lower yield than the raised-bed systems. The higher yields for the raised-bed treatments are attributed to better surface drainage than the smooth surface tillage systems NT and TA. Crop rotation had no effect on yield. The 1994 yield on the Vaiden soil were lower than 1993, and neither tillage nor crop rotation had any effect on yield. The lack of yield difference and the lower yield may have been due to stunting from post emergence herbicide injury.

On the Leeper soil for 1993, there was no corn yield difference between tillage and crop rotation systems. The 1994 Leeper site indicated an interaction between raised-bed systems and smooth tillage systems. The raised-bed treatments RT1 corn following RT2 soybeans, FPTB soybeans followed by FPTB corn and MT bed wheat-doublecrop NT soybeans followed by NT corn produced higher yield than smooth tillage systems (NT corn and MT wheat-doublecrop NT soybeans followed by NT corn), but were not different from CTB and RT1 corn. Continuous RT1 and CTB corn yields, however, were not different from MT wheat-doublecrop NT soybeans followed by NT corn. These results were similar to Vaiden soil in 1993, which showed higher yield for raised-bed systems. However, crop rotation had no effect on corn yield.

Table 1. 1993-1994 rainfall at Prairie Research Unit, Prairie, MS and Northeast Mississippi Branch Station, Verona, MS.

Month	Prairie[1]		Verona[2]	
	1993	1994	1993	1994
	in.	in.	in.	in.
May	4.40	3.27	5.54	4.39
June	2.92	12.92	4.36	7.57
July	4.60	11.10	2.04	9.57
August	5.03	1.14	5.51	2.91
September	4.80	5.56	6.83	5.09
October	2.45	5.72	2.70	6.22
Six-month Total	24.20	39.71	26.98	35.75

[1]Prairie rainfall totals for May, June, July, August, September, and October were: 4.72, 5.04, 3.78, 2.58, 3.44, and 3.08, with a 6-month total of 25.97 inches.

[2]Verona rainfall totals for May, June, July, August, September, and October were: 4.04, 3.50, 4.49, 3.08, 3.39, and 2.61, with a 6-month total of 21.11 inches.

Table 2. Effect of tillage and rotation on wheat yield in a soybean-wheat doublecropping system in 1993-1994, at the Northeast Branch Station, Verona, MS, and at the Prairie Research Unit, Prairie, MS

	Wheat		
	1993	1994	Avg.
	---- bu/acre ----		
1. Corn-Wheat/Soybean Rotation			
A. Leeper silty clay - Verona[1]			
1. NT Corn; fb[2] MT - Wheat NT Drill Beans	17.1	37.0	27.1
2. NT Corn; fb MTBd - Wheat NT Beans	16.4	38.2	27.3
B. Vaiden silty clay - Prairie[3]			
1. NT Corn; fb MT - Wheat NT Bean	26.2	70.0	56.3

[1] Previous crop (1991) was conventional tillage soybeans.

[2] fb=followed by.

[3] Previous crop (1982-91) was native grasses cut for hay. Since 1992 was first year of the study, data for rotation effects were not available.

Soybeans

The 1993-94 Leeper and Vaiden soils produced similar soybean yields (Table 4). The 1993 soybean grain yield on the

Table 3. Tillage and crop rotation effect on corn yield on Vaiden silty clay and Leeper silty clay soils, Prairie and Verona, MS 1993-1994.

Crop Rotation/ Tillage System	Vaiden Silty Clay[1]			Leeper Silty Clay[2]		
	1993	**1994**	**Mean**	**1993**	**1994**	**Mean**
	------------ bu/acre ------------			------------ bu/acre ------------		
I. CONVENTIONAL TILLAGE						
Continuous Corn (CTB)	92.7	89.3	91.0	88.7	126.9	107.8
I. STALE SEEDBED SYSTEMS						
A. **Continuous Corn**						
1. No Tillage (NT)	72.0	76.8	74.4	84.31	13.4	98.8
2. Ridge Tillage (RT1)	100.4	76.3	88.3	100.4	121.9	111.2
3. Turf Aerator-Renovator (TA)	62.1	84.4	73.2	—	—	—
B. Corn-Soybean(Bn) Rotation (2-year)						
4. RT2 Bn; fb[3] RTl Corn	109.2	82.4	95.4	93.81	36.61	15.2
5. FPTB Bn; fb FPTB Corn	—	—	—	—	—	—
C. Corn-Wheat/Soybean Doublecrop Rotation (2 year)						
6. MT Wheat NT Bn; fb NT Corn	56.2	76.8	66.5	—	—	—
7. NT Corn; fb MT Wheat NT Bn	—	—	—	92.3	109.6	100.9
8. NT Corn; fb MT Bed Wheat NT Bn	—	—	—	100.0	138.1	119.7
LSD 0.05	17.7	NS		NS	20.2	
CV%	14.4	26.8		16.9	11.4	

[1] Previous crop was native grasses for hay production from 1982-91. Prior to initiation of the study, the site was disked twice and harrowed.
[2] Previous crop (1991) was conventionally tilled soybeans.
[3] fb=followed by.

Table 4. Tillage and crop rotation effect on soybean yield on Vaiden silty clay and Leeper silty clay soils, Prairie and Verona, MS, 1993-1994.

Crop Rotation/ Tillage System	Vaiden Silty Clay			Leeper Silty Clay		
	1993	**1994**	**Mean**	**1993**	**1994**	**Mean**
	------------ bu/acre ------------			------------ bu/acre ------------		
I. CONVENTIONAL TILLAGE						
Continuous Soybean (CT)	41.5	34.5	44.2	31.2	41.7	37.2
II. STALE SEEDBED SYSTEMS						
A. **Continuous Soybean (Bn)**						
1. No Tillage (NT)	40.7	33.7	35.5	38.6	41.7	34.3
2. Ridge Tillage (RT2)	29.2[1]	37.4	42.3	21.5[1]	40.5	32.8
3. Turf Aerator-Renovator (TA)	40.7	37.8	41.5	—	—	—
B.. Corn-Soybean Rotation (2-year)						
4. **RTl** Corn; fb[3] RT2 Bn	41.2	36.4	43.6	37.7	41.5	39.6
5. FPTB Corn; fb FPTB Bn	—	35.5	35.5	—	49.7	—
C. Corn-Wheat/Soybean Doublecrop Rotation (2-year)						
6. NT Corn; fb MT Wheat NT Bn	42.7	-[2]	—	35.5[3]	23.93	29.7
7. NT Corn; fb MT Bd Wheat NT Bn	—	—	—	28.1	26.0	27.1
LSD 0.05	6.8	NS		7.5	5.7	
CV%	11.9	13.4		18.4	11.1	

[1] Low yield is due to death caused by stem canker.
[2] No yield data due to stand failure and an extremely late replanting date.
[3] Drilled soybeans.
fb=followed by; NS=not significant.

Vaiden soil showed no difference between continuous CT, NT, and TA and rotations of RT1 corn followed by RT2 soybean, and NT drilled doublecropped soybeans, but all produced higher yield than continuous RT2 soybeans. The lower continuous RT2 soybean yield in 1993 is attributed to a severe infestation of stem canker, which caused plant death in this treatment but did not effect other treatments. In 1994, all tillage and crop rotation, except NT soybeans doublecrop following MT wheat produced similar yields. NT doublecrop soybeans replanted July 5, 1994, because poor stands from excessive rainfall in June, followed by a dry August, resulted in no harvestable yield.

Soybean yield on the Leeper soil for 1993 varied with tillage and crop rotation. Continuous NT and CT soybeans, and rotations of E 1 corn followed by RT2 soybeans and NT corn followed by NT doublecropped soybeans drilled into wheat stubble were not different in yield, but all produced higher yields than RT2 continuous soybeans. Lower yields on RT2 continuous soybeans were due to stem canker disease, which caused plant death but had no effect on other treatments. In 1994, stem canker had no effect on any treatments. Continuous CT, NT, RT and RTI corn followed by RT2 soybeans produced similar yields, which were higher than 30-inch and drilled no-till doublecrop soybeans. FPTB corn followed FPTB soybeans, however, produced the highest yield (49.7 bu/ac re) of all treatments. Lack of yield differences between CT and NT soybeans on both sites in 1993 and 1994 is in contrast to previous tillage research on Prairie soils (Buehring et al., 1981, Buehring et al., 1988; Hairston et al., 1984; and Hairston et al., 1990), who reported that NT soybeans with the burndown herbicide applied at planting produced lower yield than CT. The contrasting results may possibly be because of normal or above normal rainfall during the 1993 and 1994 growing season and/or earlier burndown herbicide applications (2 to 3 weeks before planting) in 1993 and 1994.

Summary

Preliminary data indicated that both corn and soybean tillage systems showed difference in response. Soybean stale seedbed systems (TA, NT, RT, and FPTB) yields were equal to or above CT on both soils. However, corn yields were generally higher on raised beds (RT1, CTB) than on nonraised-bed treatments (TA, NT and MT wheat-NT Bn followed by NT corn), especially when above-normal rainfall occurred. Neither corn nor soybeans in a 2-year crop rotation showed improved yield response due to rotation. MT wheat and NT doublecrop soybeans in 30-inch rows on Leeper soil produced lower yield than monocrop soybean tillage and rotation treatments in 1993 and 1994. The doublerop drill beans on the Leeper site produced yield equal to NT monocrop beans in 1993, but yields were lower in 1994. Yield of doublecrop soybeans (30-inch row) on the Vaiden site were equal to monocrop CT and NT soybeans in 1993, but lower in 1994. Excessive rainfall in June and July, 1994, followed by a dry August, resulted in no yield from doublecrop NT soybean treatment. These studies will be continued in order to determine the long-term effects of tillage and rotation systems on both corn and soybean yield.

Literature Cited

Buehring, N.W., S.R. Spurlock, N.C. Edwards, D.B. Reginelli, and M.A. Blaine.1988. Net returns for soybean reduce tillage system on three land resource areas. p. 72-75. Proceedings 1988 Southern Conservation Tillage Conference, Tupelo. MS. MAFES Special Bull. **88-1.**

Buehring, N.W., ED. Whisler, and J.K. Young. 1981. Soybean response to various minimum tillage systems on a silty clay soil. p. 5 *In* Abst. of Technical Papers, S. Branch of Am. SOC.of Agron.

Hairston, J.E., W.F. Jones, P.K. McConnaughey, L.K. Marshall, and K.B. Gill.1990. Tillage and fertilizer management effects on soybean growth and yield on three Mississippi soils. J. Prod. Agric. 3:317-323.

Hairston, J.E., J.G. Miller, D.L. Lyton, L.K. Marshall, and J.O. Sanford. 1987. Effect of soil depths, O.M., and rainfall on soybean yield in the Mississippi Blackbelt. p.8. *In* Abst. of Technical Papers, S. Branch of Am. SOC.of Agron. Nashville, TN.

Hairston, J.E., J.O. Sanford, J.C. Hayes, and L.L. Reinschmidt. 1984. Crop yield, soil erosion, and net returns from five tillage systems in the Mississippi Blackland Prairie. J. Soil and Water Cons. 39:391-395.

SAS Institute Inc. 1991. SAS User's guide: Statistics. 6.03 ed. SAS Institute, Cary, NC.

U.S. Army Corps of Engineers and USDA, SCS. 1990. Tombigbee River Basin joint study.

USDA 1989. The second RCA appraisal. Soil, water, and related resources on non-federal land in the U.S. Analysis of conditions and trends.

Effect of Burndown Herbicide, Tillage, and N Rate on Fall Growth of Sod-Seeded Ryegrass

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Introduction

Ryegrass *(Lolium multiflorum* Lam.) is grown in Mississippi as a fall and winter annual forage crop for beef and dairy production. Ryegrass provides high quality forage in the fall when summer grasses are maturing and decreasing in quality.

Traditionally, ryegrass has been seeded into a conventionally prepared seedbed. Ryegrass is typically grown on highly erodible soils as defined by the Natural Resources Conservation Service (NRCS). It should not be seeded in a conventionally prepared seedbed unless the soil is not erodible. Establishment of ryegrass into a live sod or herbicide-treated sod offers alternatives to the prepared seedbed. However, reduced earliness and yield have been reported with these no-till treatments (Brock et al., 1992 ; Ingram et al., 1993; and Lang, 1989).

Summer fallow with herbicide or tillage 30 days prior to seeding allows moisture to accumulate, thus giving the ryegrass needed moisture for early fall growth (Brock et al., 1992). This experiment was conducted to determine the effect of burndown herbicide, tillage, and N rate on fall growth of sod-seeded ryegrass.

Methods and Materials

This study was conducted at Mississippi State University's Leveck Animal Research Center, Starkville, MS, on a Savannah fine sandy loam soil from fall 1992 to spring 1994 in a predominantly crabgrass *(Digitaria sanguinalis* (L.) Scop.) sod. The experiment was a randomized complete block design with four nitrogen (N) rates and three seedbed treatments replicated four times. The four N rates were *0,* 50, 100, and **150** lb N per acre; the three seedbed treatments were burndown herbicide plus residue removal prior to seeding, live sod mowed close just prior to planting, and rototilled.

Herbicide application and tillage were done the first week of August each year 6 weeks prior to seeding. The first year, 2 pints of Gramoxone@ (paraquat) per acre was the burndown herbicide applied on Aug. 11, 1992; the second year Roundup@ (glyphosate) at 2 qt/A was used to burn down the sod on Aug. 10, 1993. The planting date for first year was Oct. *7,* 1992; the second year it was Sept. 24, 1993.

The planting rate was 35 lb/A of 'Marshall' ryegrass planted with a Tye no-till drill on an 8-inch row spacing. All plots were repacked with tractor wheels prior to seeding. The N rates were applied shortly after ryegrass had emerged to a good stand about 3 weeks after planting. Other fertilizer nutrients were applied according to soil test each year. One quart of Weedmaster@ was applied Feb. 16, 1994 for broadleaf weed control. Fifty pounds N/A as ammonium nitrate were applied in February 1992 to all plots. Ryegrass plots were harvested five times in 1992-1993 and four times in 1993-1994. Stand and cover were estimated visually three times each year. Data were analyzed using computer-based ANOVA procedures (SAS, 1985).

Results and Discussion

Ryegrass stands were good both years of the study. Stand estimations ranged from **60** to 1oo%, with full stands achieved in all plots by March of each year. Tilled plots had significantly higher stands than either herbicide burndown or live sod ($P \leq 0.05$) early in the fall, but later in the spring there was no difference (data not shown).

N rates had no effect on percent stand at any observation date either year. Tilled soil produced significantly higher ryegrass cover than either burndown or live sod each year early in the season ($P < 0.05$). Ryegrass cover from either sod plot was too low in the November-December months to produce good yields for fall grazing programs (data not shown). Only the tilled plots in 1992 produced enough ryegrass in the fall to utilize.

The December 1992 ryegrass yield from tilled plots was significantly higher than for either herbicide or live sod plots (Table 1). The 50, 100, and 150 lb/A N rates applied to tilled plots in fall 1992 had high enough forage yields to have been grazed, whereas neither sod at any N rate had sufficient fall forage growth either year (Tables I and 2). Ryegrass sown in sod was not grazable until March of each year, regardless of N rate. In the second crop year, very little growth occurred until late February and early March because of an extremely dry summer and fall (Figure 1, Table 2). Total ryegrass yields in tilled plots were 1.3 to 1.9 times higher than total yields in herbicide treated or live sod plots.

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Table 1. Ryegrass yield as affected by seedbed and N rate, 1992-1993.

Seedbed & N Rate	12/3/92	2/1/93	3/11/93	4/5/93	5/4/93	Total
			Harvest Date			
			ib/A			
Burndown						
0	126	40	34	1,097	1,279	2,576
50	518	154	554	1,960	1,321	4,508
100	427	262	954	2,196	1,262	5,100
150	441	524	1,687	2,533	1,407	6,591
Live Sod						
0	105	40	0	807	1,390	2,342
50	308	85	453	1,729	1,245	3,820
100	217	97	429	2,153	1,347	4,243
150	238	234	1,137	2,550	1,228	5,387
Tilled						
0	413	68	24	1,097	1,100	2,703
50	3,495	1,020	1,031	1,770	1,066	8,382
100	2,458	1,458	1,629	1,767	989	8,301
150	2,907	2,131	2,251	2,512	1,159	10,959
LSD (0.05)	320	171	159	171	196	573
Seedbed	***	***	***	NS	***	***
Nitrogen	***	***	***	***	NS	***
Seedbed*N	***	***	***	NS	NS	NS

*** P <0.001

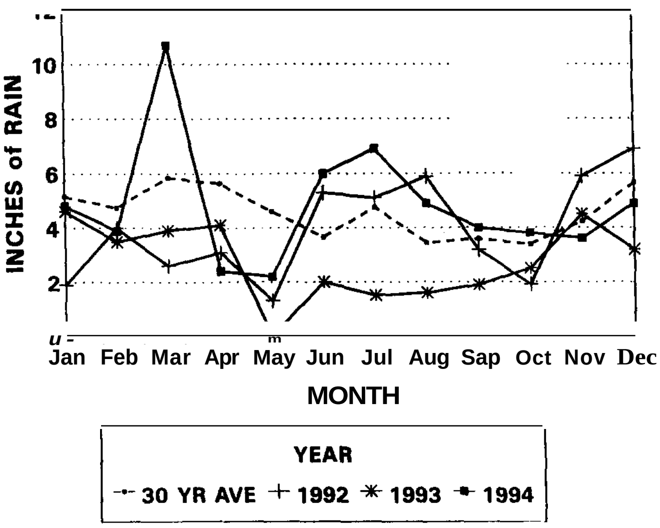

Figure 1. Monthly rainfall, 1992-1993, Mississippi State University.

Higher rainfall in July and August 1992 than the same period 1993 accounted for more fall growth in 1992 than 1993 (Figure 1). The tilled plots in 1992 accumulated more moisture than either herbicide burndown or live sod plots, thus producing higher ryegrass yield. The below-normal rainfall during May through October 1993 apparently depleted the soil of moisture, which impacted fall 1993 growth of ryegrass until early 1994. Even the tilled plots in 1993 had insufficient fall growth to utilize.

Table 2. Ryegrass yield as affected by seedbed and N rate, 1993-1994.

Seedbed & N Rate	1-24-94	3-15-94	4-11-94	5-9-94	Total Yield
		Harvest Date			
		lb/A			
Burndown					
0	16	317	939	1,118	2,390
50	51	390	1,118	1,123	2,682
100	65	663	1,428	1,363	3,519
150	58	840	1,770	1,450	4,117
Live Sod					
0	17	263	1,061	1,164	2,505
50	66	643	1,365	1,179	3,253
100	73	597	1,376	1,133	3,178
150	83	886	1,809	1,358	4,136
Tilled					
0	14	429	1,117	980	2,540
50	174	1055	1,463	863	3,555
100	101	1509	1,865	945	4,439
150	158	2066	1,826	970	5,021
LSD (0.05)	91	244	231	230	462
Seedbed	*	***	***	***	***
Nitrogen	**	***	***	*	***
Seedbed*N	NS	***	*	NS	**

* P <0.05
** P <0.01
*** P <0.001

Summary

Tilled plots produced higher yields in the fall, whereas the no-till plots produced more in the spring. There was generally no difference between planting into live annual sod and planting into herbicide-treated sod. There was a 1,000 to 1,500 lb/A advantage to using a herbicide burndown in a wet year; however, there was no advantage to using a burndown herbicide in a dry year. The warm-season grasses were sufficiently dormant by the end of September to not interfere with the growth of the ryegrass.

It should be noted that this study was located in North Mississippi; summer grasses may remain sufficiently active in South Mississippi to warrant suppression. There was an inhibitory factor within both the sod treatments that retarded fall growth of ryegrass compared with ryegrass growth in tilled plots.

Although ryegrass responded to N when applied to either sod, the N response was much greater for ryegrass growing in tilled soil. This reduction was alleviated by spring and, in fact, the sod plots had higher yields in May than tilled plots. Similar results have been previously observed (Lang, 1989; Lang et al., 1992).

References

Brock, B., J. Murphey, B. Johnson, D. Lang, and D. Ingram. 1992. Overseeding winter annuals into volunteer summer annual sod. 1992 Southern Conservation Tillage Conf. Tenn. Agri. Exp. Stn. Special Publ. 92-01. p. 34-37.

Ingram, D., W. Addison, and R. Hardin. 1993. Influence of conservation tillage on ryegrass and steer performance. 1993 Southern Conservation Tillage Conf. p. 57.

Lang, D. 1989. Comparative effects of tillage on winter annual forage production. 1989 Southern Conservation Tillage Conf. Univ. of Florida, IFAS. Special Bull. 89-1. p. 57.

Lang, D., D. Ingram, B. Brock, and B. Johnson. 1992. Establishment of winter forages into summer annual or perennial grass sods. 1992 Southern Conservation Tillage Conf. Special Publ. 92-01. Tenn. Agri. Exp. Stn. Special Publ. 9992-01. p. 94-97.

SAS Institute, Inc. 1985. SAS user's guide: Statistics. SAS Inst., Inc., Cary, NC.

Fluometuron Interactions in Crop Residue-Managed Soils

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Abstract

This paper reviews a series of studies concerning fluometuron (N,N-dimethyl-N'-[3-(trifluoromethyl)-phenyl]urea) interactions in soil and herbicide-desiccated crop residues. The objective of these studies was to evaluate effects of tillage and cover crop management on fluometuron sorption and degradation. Length of equilibration time and organic C level appeared to be the dominant factors influencing fluometuron sorption quantity and kinetics. Related to these factors, resident time and plant surface accumulation of organic residues may influence the potential for subsequent movement in soil. Fall-seeded ryegrass *(Lolium multiforum)* cover in a cotton *(Gossypium hirsutum* L.) cropping system enhanced biological soil quality and the potential for fluometuron degradation. Fluometuron was more rapidly degraded in annual ryegrass residues and conventional tillage (CT) or no-tillage (NT) soils under a fall-seeded annual ryegrass cover crop than in soils without residue.

Introduction

Fluometuron is widely used to control broadleaf and grass weeds in cotton. The adoption of residue management practices may influence the effectiveness of fluometuron as an herbicide and its persistence in soil. Higher organic matter levels in no-tillage soils can enhance sorption (Locke, 1992; Brown et al., 1994) and unextractability (Locke and Harper, 1991) of herbicides in soil. Tillage effects on herbicide degradation are mixed, but metabolism of herbicides may differ between no-tillage and conventional-tillage soils (Locke and Harper, 1991).

Promotion of management practices that enhance plant residue accumulation on the soil surface necessitates research addressing potential environmental impacts of these systems. Plant residues have the potential to intercept and retain surface applied herbicides. Subsequent mobility of the herbicide in runoff water or in leachate may be influenced by herbicide retention at the soil surface. This paper reviews results from a series of studies concerning fluometuron interactions in soil and cover crop residue. The objective of these studies was to evaluate the effects of tillage and cover crop management on fluometuron sorption and degradation.

Materials and Methods

Effects of Tillage on Sorption to Soil

Batch sorption techniques were used to characterize fluometuron sorption kinetics in surface (0-5 cm) **Dundee** silt loam soil (fine-silty, mixed, thermic Aeric Ochraqualf) from conventional tillage and no-tillage soybean *(Glycine max)* plots (Table 1). Fluometuron dissolved in 0.01 *M* CaCl, solution was added to soil (18 mL solution to 3 g air-dry soil). Initial fluometuron concentrations in the sample solutions were 0.286, 1.41, and 7.03 mol L^{-1}. The fluometuron solutions added contained 134 Bq mL-' of uniformly ring labelled ^{14}C fluometuron (specific activity 356 MBq $mmol^{-1}$).

Samples were prepared by weighing 3.0 **g** air-dry soil into 25-mL glass centrifuge tubes, and adding 15 mL of 0.01 *M* CaCl, solution. After 30 minutes, 3-mL herbicide solution (0.01 *M* $CaCl_2$) was carefully added to minimize disturbance of the soil settled at the bottom of the tube. The tubes were then sealed with teflon-lined caps and shaken (1, 2, 5, 15, or 30 min; or 1, 3, 24, 48, 72, or 96 hours) at room temperature (25 °C). After shaking, samples were centrifuged, and two 1-mL aliquots of supernatant were counted for ^{14}C radioactivity. Each shaking time was run in triplicate, and the experiment was repeated.

The difference between initial (C_0 as pmol L^{-1}) and final (Cs) herbicide concentration was attributed to sorption (xm as μmol kg^{-1}). Fluometuron sorption kinetics were described using a three-site, reversible model (Gaston and Locke, 1994), and sorption at selected shaking times (1, 24, and 96 hours) was evaluated using the Freundlich equation ($xm = K_f C_S{}^{1/n}$). Nonlinear regression was used to calculate Kf and n-1 coefficients in the Freundlich equation.

Table 1. Characteristics of Dundee silt loam (0 - 5 cm) in conventional tillage (CT) and no-tillage (NT).

Tillage	pH (1:l) 0.01 *M* CaCl,	Organic C e ke-'
CT	5.16	10.2
NT	5.54	16.7

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Sorption to Cover Crop Material and Soil

Fluometuron sorption was evaluated in Dundee silt loam soil, and rye *(Secale cereale),* hairy vetch *(Vicia villosa),* sampled from the study area described by Wagner et al. (1995). The cover crop material was collected 4 weeks following desiccation with paraquat. The samples were stored at 5 "C until use. Samples were prepared by weighing 1 g moist soil or moist plant residue into 25-mL glass centrifuge tubes. Fluometuron dissolved in 0.01 *M* $CaC1_2$ solution was added to the material (12 mL solution to 1 g, fresh weight). Initial fluometuron concentrations in the solutions were 6.50, 13.8, 23.1, 97.3, and 189.9 pmol $L^{-1.}$ Radioactivity in the fluometuron solutions was 353 Bq $mL^{-?}$ The tubes then were sealed with teflon-lined caps and shaken for 48 hours at 5 °C. The low temperature was used to minimize potential degradation during the 48-hour equilibration.

At the end of 48 hours, samples were filtered and centrifuged, and two 1-mL aliquots of supernatant were counted for radioactivity. Separate aliquots were analyzed by HPLC to determine if degradation occurred during equilibration. Parameters of the HPL C analysis included fluorescence (Ex 294 nm, Em 329 nm) and ^{14}C detection; Econosil reverse-phase column; flow rate 1 mL min-'; gradient mobile phase acetonitrile:water. The HPLC analysis did not indicate the presence of fluometuron metabolites.

Effects of Tillage and Cover Crop on Degradation

Fluometuron degradation in surface (0-2 cm) soils and ryegrass residues was assessed in the laboratory using ^{14}C-labeled fluometuron. Five g of soil and 2 g of cover crop residue were placed in 50-mL polypropylene tubes and treated with an aqueous solution of fluometuron to attain 9.7 µmol kg^{-1} fluometuron (5.89 x lo^5 Bq $kg^{-1)}$. Soils were adjusted to 32% (w/w) moisture and ryegrass residues were adjusted to 100% moisture (w/w), and all samples were incubated at 28 °C. Fluometuron and metabolites were extracted with methanol in samples taken 0, 4, 11, and 17 days after treatment. Analysis of processed extracts was by thin-layer chromatography/linear imaging scanning (chloroform:ethanol, 9 5 5 v/v) (Ross and Tweedy, 1973), and unextractable ^{14}C was quantified by oxidation of extracted samples and liquid scintillation counting.

Results and Discussion

Effects of Tillage on Sorption to Soil

Sorption kinetics between surface soils from two tillage systems were compared using the 1.43 pmol L^{-1} initial fluometuron concentration (Figure 1). The sorption process was almost completed by 24 hours, although some sorption continued through 96 hours for both soils. Sorption was more rapid in the NT soil. The Freundlich sorption coefficient (K_f) was calculated for 1-, 24-, and 96-hour shaking times (Table 2). Fluometuron sorption was higher in NT than CT, as in-

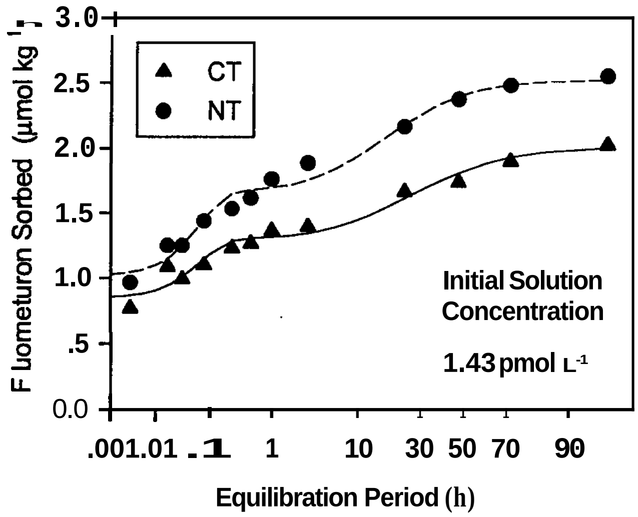

Figure 1. Sorption kinetics of fluometuron in Dundee conventional tillage and no-tillage soil during a 96-hour equilibration. Symbols are means of observed values, and curves represent values predicted by a three-site, reversible model.

dicated by higher K_f values for all three shaking times. The K_f values for soils from both tillage systems also increased with shaking time, supporting the previous kinetic data. Sorption was nonlinear (n^{-1} < l), and the exponent parameter was similar for both soils and all shaking times (Table 2). Nonlinear characteristics indicate that sorption decreased as initial herbicide concentration increased.

Sorption to Cover Crop Material and Soil

Herbicide sorption was greatest in the rye and lowest in soil (Table 3). The surface area and number of sorption sites of the plant residues were likely greater than that of the soil, but little is known about the reactivity of herbicides with functional groups in decayed plant material. However, the plant materials were heavily colonized by fungi and bacteria (Wagner et al., 1995), and structural components of microbes may have strong sorptive capabilities.

Cell components (lipids, proteins, soluble sugars, and poly-

Table 2. Freundlich parameter coefficients characterizing the effects of tillage on fluometuron sorption at selected equilibration times.

	Conventional Tillage				No-Tillage			
Time (h)	Kf[1]	s.e.[2]	[n-1][3]	s.e.[2]	Kf'	s.e.[2]	[n-1][3]	s.e[2]
1	1.04	0.025	0.83	0.017	1.53	0.025	0.85	0.018
24	1.44	0.033	0.85	0.018	2.02	0.024	0.85	0.007
96	1.81	0.025	0.83	0.014	2.45	0.031	0.85	0.010

'Freundlich sorption coefficient.
[2]Asymptotic standard error.
[3]Freundlich exponent.

Table 3. Freundlich parameters describing fluometuron sorption in rye. hairv vetch. and Dundee soil.

Sorbent	K_f[1]	s.e.[2]	$[n^{-1}]$[3]	s.e.[2]
Rye	21.8	1.11	0.96	0.01
Hairy Vetch	28.0	4.25	0.84	0.03
Dundee Soil	2.60	0.26	0.86	0.02

'Freundlich sorption coefficient.
[2]Asymptotic standard error.
[3]Freundlich exponent.

saccharides) in the plant residue material were likely consumed by microbes in initial decomposition stages. However, basic plant structural components were intact. Of these constituents, relative abundance in plant material is generally cellulose > lignin > suberin > cutin, and all are resistant to decomposition. Dao (1991) observed that cellulose extracted from wheat straw had low affinity for metribuzin, but that the acid-detergent fiber fraction (cellulose/lignin polymers) had a much higher affinity for metribuzin. Silica may also play a role in the sorption of herbicides to the plant residue. Substantial silica deposits in epicuticular cells have been observed in many grass species.

Effect of Tillage and Cover Crop on Degradation

Soil organic carbon in the surface (0-2 cm) soil was 74% higher in NT compared to CT soils without ryegrass, and 108% higher in NT compared to CT soils from plots with annual ryegrass (Wagner et al., 1995). After 4 years of NT, minimal effects on soil microbial populations were observed in the 0-2 cm surface soil. The annual ryegrass cover crop stimulated all microbial populations evaluated in the surface soil for all sampling periods in both tillage regimes (Wagner et al., 1995). Transient increases in microbial populations due to the ryegrass cover crop were most pronounced in CT plots compared to the NT plots in the 2-10 cm depths. Soil aryl acylamidase and esterase activity and microbial biomass were greatest in NT-ryegrass plots (0-2 cm) with no differences in these parameters attributable to tillage or ryegrass at 2- to 10-cm depth.

Soils from the NT ryegrass plots exhibited the greatest incorporation of fluometuron into unextractable components (data not shown). Fluometuron degradation occurred most rapidly in soils from NT and CT plots with ryegrass (half-life 8 days) (Figure 2). Half-lives of 10.5 days were observed in ryegrass residues and 15 to 16 days for CT and NT soils, respectively, from plots without the ryegrass cover crop.

Microbial populations associated with the ryegrass soils were significantly greater than those of the bare soils (Wagner et al., 1995). All of the soils have received annual applications of fluometuron for at least 4 years. Thus, a microbial communit y capable of rapid fluometuron metabolism most likely enhanced fluometuron degradation under ryegrass.

Trifluoromethyl aniline was infrequently detected, and when observed was less than 2% of recovered ^{14}C.

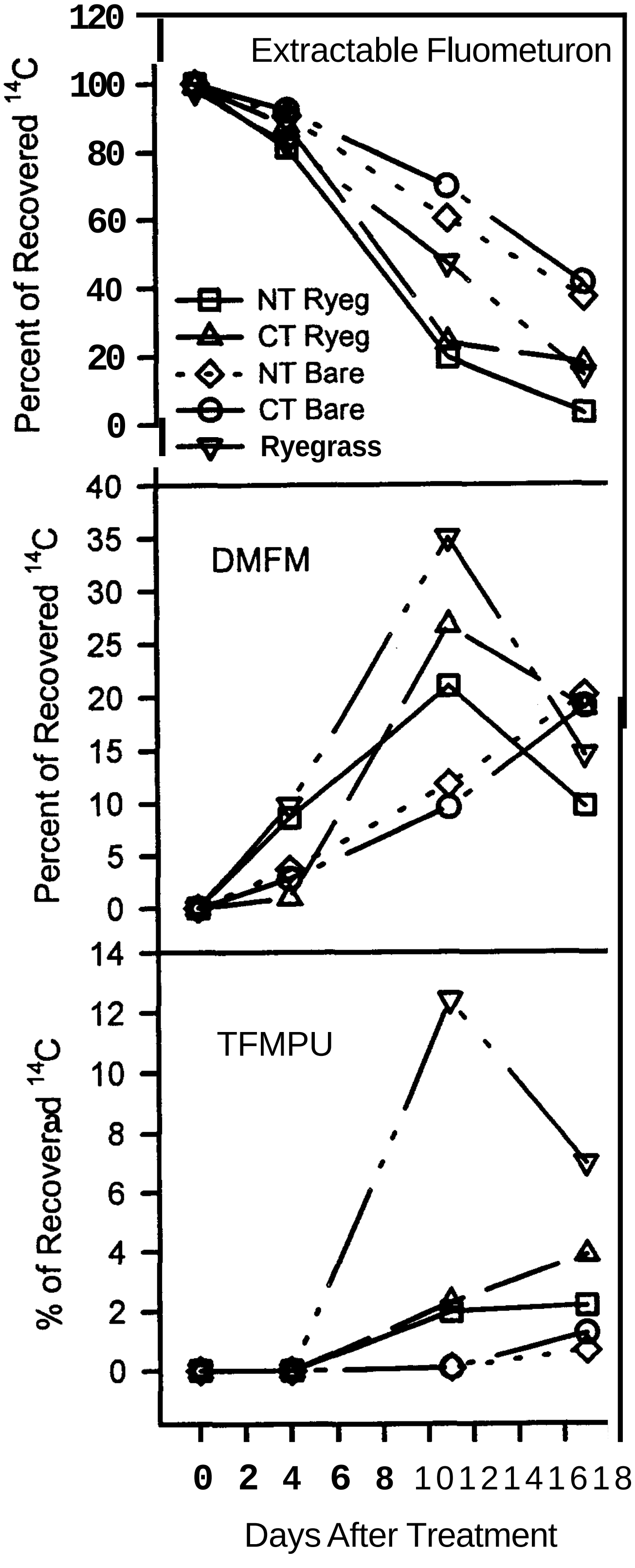

Figure 2. Interaction of annual ryegrass cover and tillage on fluometuron persistence and appearance of desmethyl fluometuron and triflouromethylphenylurea 17-day incubation study.

Desmethyl-fluometuron (DMFM) was the primary accumulating metabolite observed in soil. Trifluoromethylphenylurea (TFMPU) was only observed after accumulation of DMFM, and the greatest accumulation of TFMPU was in ryegrass residues.

References

1. Brown, B.A., R.M. Hayes, D.D. Tyler, and T.C. Mueller. 1994. Effect of tillage and cover crop on fluometuron adsorption and degradation under controlled conditions. Weed Sci. 42:629-634.
2. Dao, T.H. 1991. Field decay of wheat straw and its effects on metribuzin and s-ethyl metribuzin sorption and elution from crop residues. J. Environ. Qual. 20:203-208.
3. Gaston, L.A., and M.A. Locke. 1994. Predicting alachlor mobility using batch sorption kinetic data. Soil Sci. 158:345-354.
4. Locke, M.A. 1992. Sorption-desorption kinetics of alachlor in surface soil from two soybean tillage systems. J. Environ. Qual. 21:558-566.
5. Locke, M.A., and S.S. Harper. 1991. Mctribuzin degradation in soil: II. Effects of tillage. Pestic. Sci. 31:239-247.
6. Ross, J.A., and B.G. Tweedy. 1973. Degradation of four phenylureaherbicides by mixed populations of microorganisms from two soil types. Soil Biol. Biochem. 5:739-746.
7. Wagner, S.C., R.M. Zablotowicz, M.A. Locke, R.J. Smeda, and C.T. Bryson. 1995. Influence of herbicide-desiccated cover crops on soil quality in the Mississippi Delta. *In* N.W. Buehring, W.L. Kingery (eds.), Southern Conservation Tillage Conference for Sustainable Agriculture Proceedings: A focus on water quality. Jackson, MS.

Effect of Soybean-Corn Rotation and Tillage on Ground Residue Cover and Canopy Development

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Introduction

Topography in northeastern Mississippi ranges from level to sloping, and the sloping soils are often classified as highly erodible, based on regulations of the 1985 and 1990 Food Security Acts. For row-crop production to meet conservation compliance on these sloping soils, terraces and/or grass strips may be necessary (Argus, 1993). Crop residue and winter vegetation ground cover management have the potential to be effective methods for reducing erosion and thereby meeting compliance standards. Tillage practices directly impact the amount of crop residue and winter vegetation that remain on the soil surface. Therefore, studies were initiated to determine the influence continuous cropping and rotations of corn and soybeans, and corn and wheat with doublecropped soybeans in stale seedbed (no preplant tillage) and conventional tillage systems, have on winter vegetation canopy ground cover and ground residue cover.

Materials and Methods

Studies were conducted as randomized complete block designs with four replications on Vaiden and Leeper silty clay soils at Prairie and Verona, MS, respectively. A 100-pin camline with pins spaced 6 inches apart was used to measure ground residue cover (GRC) and winter vegetation canopy cover (VCC) development in three of four replications. Vegetation and pieces of crop residue under each pin were counted and expressed as a percentage (Sloneker and Moldenhauer, 1977).

The following continuous cropping tillage treatments were evaluated on both sites: (1) no-tillage (NT) corn; (2) ridge-tillage (RT1) corn (planted no-till and cultivated once with a high-clearance cultivator equipped with ridgers); (3) turf aerator (TA) corn, with turf aerator knives operated one month prior to planting at 10° angle from vertical and at a 4 to 6-inch depth at Prairie; (4) conventional raised-bed tillage (CTB) corn (disked, chiselled, bedded, do-alled before planting, and cultivated once); (5) NT soybeans; (6) ridge tillage (RT2) soybeans (planted no-till and cultivated twice with high-clearance cultivator equipped with ridgers); (7) TA soybeans; and (8) conventional smooth seedbed tillage (CT) soybeans (chisel, disk, followed by do-all before planting and cultivated twice during the growing season).

The following tillage/crop rotation treatments were evaluated on both sites: (1) RTl corn followed by RT2 soybeans; (2) RT2 soybeans followed by RT1 corn; (3) NT corn followed by minimum tillage (MT) wheat (disked twice after corn harvest followed by wheat do-alled before planting) with NT doublecrop soybeans; (4) MT wheat with NT doublecrop soybeans followed by NT corn; (5) NT corn followed by MT Bed (MTBd) wheat and NT doublecrop soybeans (Verona site); and (6) MTBd wheat with NT doublecrop soybeans followed by NT corn (Verona site).

Corn stale seedbed systems (TA, NT, and RTl) received a tank mixture of a burndown and preemergence herbicides, after planting corn. CTB corn also received the same preemergence herbicides. Corn was planted at 1.5 seeds/ft row in 30-inch rows with 160 lb N/A applied when corn was 12 to 16 inches tall.

A broadleaf herbicide was applied mid-February to mid-March for weed control on all continuous stale seedbed monocrop soybeans and wheat doublecrop soybean treatments. Two weeks prior to planting soybeans, a burndown herbicide was applied to continuous soybean stale seedbed systems (RT2, TA, and NT) and rotation (RT1 corn followed by RT2 soybeans) treatments. Soybeans were planted in 30-inch rows with 9 seeds/ft of row. Preemergence herbicides were applied to rotation (RT1 corn followed by RT2 soybeans) and continuous CT, RT2, TA, and NT soybeans. All wheat NT doublecrop soybean treatments received a burndown herbicide application at soybean planting. Soybeans, wheat, and corn were harvested with a combine equipped with a chopper that spread the residue across a 20-foot wide plot.

Wheat plots were planted in the fall of 1992 and 1993 in 7.5-inch rows, using 20 seed/ft of row. Nitrogen was applied broadcast to wheat plots in the spring at 120 lb/A. Data were subjected to statistical analysis (SAS, Cary, 1988) and me-

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ans were separated by Least Significant Difference (LSD) at the 0.05 probability level.

Discussion

Corn

Prairie. Winter VCC development was slow from October 1992 and 1993, through March 1993 and 1994, on all treatments (Table 1). Maximum VCC was 20% for RT2 soybeans followed by RT1 corn on March 8, 1993 and 42% VCC on Feb. 18, 1994. Data for GRC indicated stale seedbed treatments TA, NT, and RTl in continuous corn, and RT2 soybeans followed by RT1 corn had *56*% or more GRC on March 8, 1993 and 55% or more GRC on Feb. 18, 1994. The soybean residue in the rotation (RT2 soybeans followed by RT1 corn) had similar GRC as RTl and NT continuous corn in October and November, but was lower than NT corn in February, March, and April. The CTB corn had 26 and 15% GRC after planting in April 1993 and and April 1994. The lower GRC for CTB is a reflection of tillage operations, which destroyed VCC and GRC by mixing and burying both GRC and VCC.

Verona. Winter VCC on the Leeper was similar to the Vaiden site (Table 2). However, the MTBd wheat with doublecrop NT soybeans followed by NT corn in a rotation had 31% VCC on March 11, 1993 and, because of volunteer wheat from the previous wheat crop, had more VCC than all other stale seedbed systems. Stale seedbed corn rotation RT2 soybeans followed by RTl corn indicated that soybean residue disintegrated more rapidly than corn residue resulting in lower GRC for RT2 soybeans than NT corn in March and April 1993, and March 1994.

Stale seedbed (NT, RTl) continuous corn and corn rotation stale seedbed treatment RT2 soybeans followed by RTI corn had similar GRC. Both treatments had 53 and 76% or more GRC after planting corn April 14, 1993 and April 20, 1994,

Table 1. Effect of corn rotation and tillage on winter vegetation canopy cover and ground residue cover on a Vaiden silty clay soil from October 1992 through May 1994 at the MAFES Prairie Unit, Prairie, MS.

	1992 and 1993					
	Fall 1992			Spring 1993		
Corn Rotation/Tillage System'	**10105**	**10/23**	**11/25**	**3/08**	**4/12[2]**	**6/02**
	% Ground Residue (Canopy) Cover					
I. CONVENTIONAL TILLAGE (CTB)	94(2)	32(3)	19(5)	20(17)	26(14)	17(44)
11. STALE SEEDBED SYSTEM						
A. **Continuous Corn (C)**						
1. No Tillage (NT)	95(3)	89(7)	*86(3)*	79(9)	59(14)	30(50)
2. Ridge Tillage (RTl)	91(2)	*85(5)*	78(6)	67(18)	55(16)	7(45)
3. Turf Aerator (TA)	95(3)	90(8)	88(5)	72(4)	56(5)	23(52)
B. Soybean(Bn)-Corn(C) Rotation						
4. RT2-Bn; Fb RT1-C	–	92(0)	82(3)	56(20)	38(-)	4(39)
C. Wheat(W)/Soybean(Bn)-NT-Corn(C) Rotation						
5. MT-W-NT-Bn; Fb NT-C	–	99(0)	99(0)	80(17)	68(25)	15(77)
LSD 0.05	–	5(4)	14(NS)	14(10)	15(12)	15(11)
% CV	–	3(83)	11(95)	13(36)	18(27)	54(33)
	1993 and 1994					
	Fall 1993			**Spring 1994**		
	9/30	**11/02**	**12/13**	**2/18**	**4/14'**	**5/19**
I. CONVENTIONAL TILLAGE (CTB)	97(2)	48(3)	17(0)	25(3)	15(0)	17(16)
11. STALE SEEDBED SYSTEM						
A. **Continuous Corn (C)**						
1. No Tillage (NT)	96(4)	97(1)	96(1)	86(10)	85(13)	77(16)
2. Ridge Tillage (RT1)	95(3)	91(2)	85(6)	69(25)	89(1)	63(18)
3. Turf Aerator (TA)	90(4)	91(5)	94U)	81(14)	46(0)	47(14)
B. Soybean(Bn)-Corn(C) Rotation						
4. RT2-Bn; Fb RT1-C	---(-)	95(2)	68(30)	55(42)	37(0)	74(16)
C. Wheat(W)/Soybean(Bn)-Corn(C) Rotation						
5. MT-W-NT-Bn; Fb NT-C	--(-)	100)	96(3)	83(16)	95(0)	76(17)
LSD 0.05	NS(NS)	5(4)	16(14)	20(19)	31(10)	13(14)
% CV	3(89)	3(97)	12(18)	18(43)	27(40)	12(12)

'Tillage descriptions are listed in materials and method; Fb = followed by.
2Data collected after corn was planted 4/12/93 and 21 days after planting 3/23/94.

respectively. This was in contrast to CTB corn, which had 21%and 20%GRCafter planting April 14, 1993 and April 10, 1994.

Soybeans

Prairie Winter VCC development in the soybean treatments was slow and very similar to corn until February, and then increased dramatically from March through April, reaching 67% VCC in continuous NT beans and 86% VCC in MT wheat in April 1993, and 91 and 99% VCC in April 1994, respectively, (Table 3). The RT1 corn followed by RT2 soybeans showed less VCC cover than continuous RT2 and NT soybean March 8, 1993 and April *12*, 1993, and Feb. 10, 19994 and April 14, 1994. This may have been because of less corn residue decomposition (higher % GRC), which resulted in more ground shading for the rotation than continuous RT2 and NT soybeans. The soybean stale seedbed TA treatment after planting June 1, 1993 and May 19, 1994 had 42% and 69% GRC, respectively. The continuous NT and RT2 soybeans, after planting June 2, 1993 and May 19, 1994, had 73 and 76% or more GRC compared to 8 and 12% GRC, respectively, for CT soybeans.

Verona The 1993 and 1994 results indicated that stale seedbed soybean rotation system RTl corn followed by RT2 soybean had low VCC development in April in comparison to continuous NT soybeans (Table 4). The NT and RT2 continuous soybean winter VCC for April 19, 1993 and April 20, 1994 was 53 and 24%, and 62 and 64%, respectively. This was in comparison to 11 and 17% VCC for the RTl corn followed by RT2 soybean rotation on April 19, 1993 and April 20, 1994. The rotation RT1 corn followed by RT2 soybeans GRC was higher (less corn residue decomposition) than continuous NT and RT2 soybeans in April of 1993 and 1994,

Table 2. Effect of corn rotation and tillage on winter vegetation canopy cover and ground residue cover on a Leeper silty clay soil from October 1992 through May 1994 at the MAFES Northeast Branch Station, Verona, MS.

	1992 and 1993					
	Fall 1992			Spring 1993		
Corn Rotation Tillage System'	**10102**	**10/08**	**10/26**	**12/15**	**3/11**	**4/14j**
	.... **70 Ground Residue (Canopy) Cover** - - - - - - - -					
I. CONVENTIONAL TILLAGE (CTB)	89(1)	31²	15(0)	19(3)	30(11)	21(3)
II. STALE SEEDBED SYSTEM						
A. **Continuous Corn (C)**						
1. No-Tillage (NT)	92(2)	—	92(7)	84(7)	83(9)	73(8)
2. Ridge Tillage (RT1)	91(0)	—	91(5)	77(7)	73(10)	67(11)
B. Soybean(Bn)-Corn(C) Rotation						
3. RT2-Bn; Fb RT1-C	—	—	88(9)	69(11)	59(14)	53(18)
C. Wheat(W)/Soybean(Bn)-Corn(C) Rotation						
4. MT-W-Drill-Bn; Fb NT-C	—	—	97U)	88(1)	86(9)	78(14)
5. MTBd-W-NT-Bn; Fb NT-C	—	—	85(13)	75(12)	57(31)	42(43)
LSD 0.05	—	—	8(4)	13(9)	14(11)	15(12)
% CV	—	—	6@5)	1l(74)	14(49)	17(46)
	1993 and 1994					
	1993			**1994**		
	10/01	**10/06**	**11/23**	**3/07**	**4/20³**	**5/24**
I. CONVENTIONAL TILLAGE (CTB)	84(7)	19²(1)	14(0)	29(5)	20(2)	1(45)⁴
II. STALE SEEDBED						
A. Continuous Corn (C)						
1. No-Tillage (NT)	9x3)	-(-)	95(3)	82(14)	91(0)	50(41)
2. Ridge Tillage (RT1)	83U)	-(-)	87(8)	67(20)	76(0)	6(45)⁴
B. Soybean(Bn)-Corn(C) Rotation						
3. RT2-Bn; Fb RT1-C	W1)	-(-)	82(2)	58(32)	85(32)	4(32)⁴
C. Wheat(W)/Soybean(Bn)-Corn(C) Rotation						
4. MT-W-Drill-Bn; Fb NT-C	--(-)	-(-)	100(0)	86(12)	87(12)	45(38)
5. MTBd-W-NT-Bn; Fb NT-C		-(-)	88(0)	80(10)	74(10)	26(41)
LSD 0.05	7@")	-(-)	5(2)	22(19)	1l(NS)	12(9)
% CV	3(89)	--(-)	4(61)	18(66)	9(137)	30(13)

'Tillage descriptions are listed in materials and method; Fb = followed by.
²Disked once 10/06/92 and 10/05/93, chiseled and bedded 10/17/92 and 11/12/93.
'Data collected after corn was planted 4/14/93 and 28 days after planting corn 3/23/94.
4Ridge-till **(T2)** and conventional tillage (T3) were cultivated 5/18/94.

but after planting all showed no GRC differences. Continuous soybean stale seedbed systems (RT2 and NT) had 70% or more GRC in comparison to 3% GRC for CT after soybean planting May 31, 1993 and May 24, 1994.

Conclusion

Preliminary 2-year (1993-1994) results indicated that both soils showed similar GRC and VCC development response under the same tillage and crop rotation systems. Soybean residue decomposition in the spring of each year was more rapid than corn residue under the same tillage regime. VCC development was relatively slow during the winter months but increased dramatically in March and April of each year. In the stale seedbed (TA, NT, RT1, and RT2) systems, the existing vegetation was killed with a burndown herbicide, which contributed to the GRC at planting. Conventional tillage (CTB and CT) not only destroyed VCC but also incorporated crop residue, leaving little residue (1 to 20%) on the soil surface at planting. Lower amounts of GRC on the soil surface leaves more of the soil surface area exposed to the energy of the impacting rain drops. This can result in more soil erosion, especially from intense storms, which occur more frequently in Mississippi in the spring of each year (April-July). These preliminary data indicate that NT and RT stale seedbed systems with continuous and rotations of corn and soybeans, and doublecrop MT wheat-soybeans have potential for use in conservation compliance plans.

Further work will concentrate on using these data to determine the "C" factor for each crop tillage system in predicting soil erosion, (USDA, Sci. and Ed. Admin. and Purdue Ag. Exp. Sta., 1978). Early crop stage development will be noted during GRC and VC data collection.

Table 3. Effect of soybean rotation and tillage on winter vegetation canopy cover and ground residue cover on a Vaiden silty clay from October 1992 through May 1994 at the MAFES Prairie Research Unit, Prairie, MS.

	1992 and 1993					
	Fall 1992			Spring 1993		
Sovbean Rotation/Tillage Svstem'	**10/05**	**10/23**	**11/25**	**3/08**	**4/12**	**6/02**
	% Ground Residue (Canopy) Cover					
I. CONVENTIONAL TILLAGE (CT)	–	88(0)	41(5)[4]	35(42)	13(29)	12(1)[2]
II. STALE SEEDBED SYSTEMS						
A. Continuous Soybean (Bn)						
1. No Tillage (NT)	–	90(3)	79(3)	52(30)	25(67)	73(22)[2]
2. Ridge Tillage (RT2)	–	92(0)	77(6)	50(40)	29(71)	76(21)[2]
3. Turf Aerator (TA)	–	91(1)	81(2)	50(32)	24(63)	42(32)[2]
B. Corn(C)-Soybean(Bn) Rotation						
4. RT1-C; Fb RT2-Bn	91(2)	88(4)	86(3)	76(20)	53(39)	60(33)[2]
C. Corn(C)-WheatCW)/Soybean(Bn) Doublecrop Rotation						
5. NT-C; Fb MT-W-NT-Bn	28(0)[3]	33(1)	21(16)	317(58)	6(86)	-(-)
LSD 0.05		9(2)	13(4)	13(13)	lO(18)	26(19)
% CV		7(98)	12(29)	17(19)	27(15)	26(73)

	1993 and 1994					
	Fall 1993			Spring 1994		
	9/30	**11/02**	**12/13**	**2/10**	**4/14**	**5/19**
I. CONVENTIONAL TILLAGE (CT)	-(-)	95(0)	24(2)	32(16)	12(85)	8(1)[5]
11. STALE SEEDBED SYSTEMS						
A. Continuous Soybean (Bn)						
1. No Tillage (NT)	--(-)		68(31)	50(48)	9(91)	96(1)[5]
2. Ridge Tillage (RT2)	4-)	85(2)	61(33)	41(52)	15(82)	92(2)[5]
3. Turf Aerator (TA)	4-)	92(5)	61(36)	47(45)	90(1)	76(1)[5]
B. Corn(C)-Soybean(Bn) Rotation						
4. RT1-C; Fb RT2-Bn	920)	81(4)	76(17)	69(28)	75(23)	69(3)[5]
C. Corn(C)-Wheat(W)/Soybean(Bn)Doublecrop Rotation						
5. NT-C; Fb MT-W-NT-Bn	91(7)	36(0)	45(3)	46(20)	lO(99)	--(99)
LSD 0.05	NS(11)	11(7)	17(14)	17(11)	28(25)	13(4)
% CV	5(159)	9(133)	17(65)	20(25)	55(24)	13(12)

'Tillage descriptions are listed in materials and method; Fb = followed by.
*Data was collected after soybeans had been planted 6/02/93.
'Disked twice 10/04/92 and do-alled 10/25/92.
Thiseled 10/29/92, disked 4/10/93, and do-alled 6/01/93.
5Data collected after soybeans were planted on 5/19/94.

References

Argus Agronomics, A Divison of Argus, Inc.1993. Reduced Tillage Digest for Southern Soils. p.26-27. Clarksdale, MS.

SAS Institute Inc. 1988. SAS languages guide for personal computers. 6.03 edition. SAS Inst., Inc., Cary, NC.

Sloneker, L.L., and W.C. Moldenhauer. 1977. Measuring the amounts of crop residue remaining after tillage. J. Soil Water Conserv. 32(5):

USDA, Science and Education Administration and Purdue Agricultural Experiment Station. 1978. Predicting rainfall erosion losses, a guide to conservationplanning.

Table 4. Effect of soybean rotation and tillage soybean on winter vegetation canopy cover and ground residue cover on a Leeper silty clay soil from October 1992 through May 1994 at the MAFES Northeast Branch Station, Verona, MS.

	1992 and 1993					
	Fall 1992			Spring 1993		
Soybean Rotation Tillage System'	10126	12/15	3/11	4/19	5/31	6/17
	yo Ground Residue (Canopy) Cover					
I. CONVENTIONAL TILLAGE (CT)3	83(2)	65(7)	56(12)	35(49)	4[2](0)	3(4)
11. STALE SEEDBED SYSTEMS						
A. **Continuous Soybean (Bn)**						
1. No Tillage (NT)	86(13)	65(8)	44(28)	29(53)	81[2](1)	74(10)
2. Ridge Tillage (RT2)	76(2)	56(7)	47(11)	48(24)	7O[2](0)	70(7)
B. Corn(C)-Soybean(Bn)Rotation						
3. RTl-C; Fb RT2-Bn	92(-)	73(2)	690)	73(11)	772(1)	68(9)
C. Corn(C)-Wheat(W)/Soybean(Bn) Doublecrop Rotation						
4. NT-C; Fb MT-W-Drill-Bn	32(2)	24(23)	13(47)	—(85)	—(-)	95[2](1)
5. NT-C; Fb MTBd-W-NT-Bn	16(3)	16(20)	15(37)	12(64)	—(-)	80[2](13)
LSD 0.05	16(9)	19(9)	22(13)	21(22)	17(NS)	15(NS)
% CV	16(116)	21(43)	32(30)	30(25)	15(218)	12(101)

	1993 and 1994					
	Fall 1993			Spring 1994		
	10/01	10/06	11/23	3/07	4/20	5/24
I. CONVENTIONAL TILLAGE (CT)[3]	—	—	9(0)	19(7)	35(42)	34(4)
II. STALE SEEDBED SYSTEMS						
A. **Continuous Soybean (Bn)**						
I. No Tillage (NT)	—	—	90(10)	63(34)	37(62)	76[4](4)
2. Ridge Tillage (RT2)	—	—	63(11)	59(31)	28(64)	70[4](6)
B. Corn(C)-Soybean(Bn) Rotation						
3. RT1-C; Fb RT2-Bn	86(1)	—	74(7)	63(32)	64(17)	61[4](5)
C. Corn(C)-Wheat(W)/Soybean(Bn) Doublecrop Rotation						
4. NTC; Fb MTW-NT 15N36	(12)20	(1)31	(2)31	(24)	—(99)	—(-)
5. NT-C; Fb MTBd-Wh-NT-Bn	95(2)	15(0)	8(4)	12(23)	—(99)	—(-)
LSD 0.05	7(4)	14(NS)	6(6)	16(13)	30(19)	16(3)
% CV	4(51)	35(159)	8(75)	22(32)	40(18)	22(6)

'Tillage descriptions are listed in materials and method; Fb = followed by.

[2]Data collected after soybeans were planted 5/31/93 and 6/17/93 (doublecropped beans).

[3]Chiseled 4/29/93; disked and do-alled (2X) 5/29/93.

[4]Data collected 18 days after soybeans were planted 5/06/94.

Performance of Soybean Tillage Trials in the Brown Loam Region of Mississippi

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Introduction

No-till (NT) soybean production offers producers savings in time, labor, equipment, and fuel. Reduction in soil erosion, improvement in soil organic matter, increases in surface residue, and more earthworm activity are beneficial aspects of NT for soil improvement and maintaining sustainability. Decrease in rainfall runoff, less soil evaporation, and higher soil water holding capacity are aspects of NT that are beneficial for crop production. Yet, the one aspect of NT soybean production that draws the most attention is yield performance.

In the early NT soybean research at the North Mississippi Branch Experiment Station (NMBES), yields were the primary focus of each study comparing NT with conventional-till (CT) practices. Most of these studies were located on different sites each year and very seldom did NT plots have a previous history of NT soybean production. Benefits of continuous NT soybean production were not recognized or did not develop because of poor stands and weed control. However, when researchers moved from measuring yields to other aspects of continuous NT production, yield benefits from long-term NT soybean production were discovered.

Summary of Soybean Tillage Trials Since 1978

All the studies discussed in this report are part of Mississippi Agricultural and Forestry Experiment Station (MAFES), USDA Agricultural Research Service (ARS), or joint MAFES-ARS research plots at NMBES during the past 20 years. All the studies in this report are planted in a randomized complete block design with at least four replications. Two treatments (NT and CT) were common to all studies. The CT plots involved considerable tillage that destroyed all the surface residue. The NT plots were planted using NT planters that were applicable and acceptable for NT planting at that date and time. Planters, coulters, press wheels, etc. have changed over the past 20 years and planting precision is more accurate today than when some of the early studies were conducted. In this report, we will try to highlight where past planting and weed control technology, even though best for the time, affected yields in studies.

In the early stages of NT soybean research at NMBES, sites were selected for research to try to duplicate conditions associated with high erosion in the Brown Loam areas of Mississippi. Field sites were selected that had slopes up to 12% and represented many fields that had gone from pasture to soybeans. Other field sites were selected that had moderate to severe erosion to represent conditions that existed in many longer-term soybean fields of that time. Where johnsongrass or bermudagrass was present, as was usually the case when old pastures were turned into soybean fields, producers were warned not to attempt NT soybean production. The early NT studies at NMBES were planted on sites that would be hard to manage even today with advanced production techniques, equipment, and chemicals.

Summarizing 21 first-year tillage trials that were conducted between 1978 and 1987 in old soybean fields where CT practices were used the previous year, average yields of NT plots were 21% less than the CT plots (Table 1). Fourteen percent of the one-year studies had NT yields that equaled or exceeded the CT plots. Twenty-four percent of the studies were documented as having poor or skippy stands in the NT-planted plots. Thirty-eight percent of the studies were documented as having weedy or grassy NT plots that probably further contributed to lower yields.

When site selection was considered (Table 2), the studies conducted on the steeper slopes (6-12%) experienced a higher reduction in NT yields, 44%, than the flatter slopes (2-6%), 29%, compared with CT. When previous erosion was a factor, the studies conducted on sites that were moderate to severly eroded had a higher reduction in NT yields, 32%, when compared to CT than the noneroded or slightly eroded sites, 24% when compared to CT.

Table 1. Summary of yield performance of 21 soybean tillage trials conducted at the NMBES from 1978 to 1987 where the area was in CT soybean production the previous year before the trial.

Tillage practice	Average yield of soybeans
	------- bu grain/acre -------
CT	29.35
NT	23.25

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Since pastureland was being converted into soybean fields, six studies were conducted in old pasture sites (Table 3). All of the NT plots were infested to some degree with bermudagrass and johnsongrass. The inability to control these grasses partially accounted for the 30% reduction in yields from NT plots. Doublecropping with soybeans was explored, where soybeans were planted into ryegrass fields after winter grazing was terminated, and in soybeans following wheat. Yield reduction percentages in NT soybeans compared to CT soybeans in ryegrass fields were equivalent to the 20% yield reduction in old soybean fields. A more favorable NT yield resulted with wheat-soybean doublecropping. There was only a 6% reduction in the NT yields compared to CT when soybean tillage studies were conducted after **a** wheat crop was harvested.

A change in row pattern from wide rows (36-40 inches) to narrow rows (7-10 inches) resulted in the least difference between CT and NT. The average NT yield for narrow-row soybeans was within ***2*** % of the CT narrow-row planted soybeans. These results were the main factors for encouraging producers to start using soybean drills for planting NT into old wheat stubble, resulting in yields comparable to CT with less time, labor, tillage, and equipment, and without sacrificing soil moisture due to tillage at a critical time.

Up until 1980, all the MAFES tillage trials at the NMBES were located on a different site each year. Consequently, the previous history of NT production was not taken into account. Since 1980, nine soybean studies have been continued for 3 years on the same sites and the NT plots have been located on the previous year's NT plots. The average of these studies showed NT planting in wide rows reduced soybean yields 20% the first year, 9% the second year, and 4% the third year when compared to CT (Table 5).

There were two soybean tillage studies that retained the same site for 5 years or longer where tillage plots maintained the same identity throughout the duration of the studies. When good weed control practices prevailed, average soybean yields in NT plots after 5 years of previous NT production exceeded the CT yields by an average of 6% (Table 5). It is important that weeds be closely monitored and herbicide programs thoroughly reviewed for efficacy if long-term production of NT soybeans are to be sustained. Factors causing a reduction in the NT yields during the first years of these studies had less of a yield-limiting effect after 3 years continuous NT.

Conclusion

When planting NT soybeans in wide rows into old soybean stubble, a yield reduction was observed if the previous field history was CT. The possible yield reduction was moderated by assuring proper planting practices to achieve a good stand and by using proper weed control techniques. Drilling soybeans NT into old soybean stubble has been best planting procedure for attaining the smallest yield reduction when compared to wide rows. Planting soybeans NT after wheat resulted in a 6% reduction in yield. The saving of time, fuel, labor, moisture, and equipment by no-till may more than offset this small yield loss.

In a monocropping system, planting soybeans NT for several consecutive years has resulted in NT yields similar to the CT yields. However, care must be taken to avoid a static weed control program. The rotation of an effective herbicide program for weed control is essential to maintaining long-term NT soybean production.

Table 2. Site selection influence on yield performance of soybean tillage trials at NMBES from 1978 to 1987.

Tillage practices	Site selection of trials			
	2-6% slow	6-12% slope	Noneroded site	Eroded site
	bu grain/acre			
CT	34.18	31.20	31.31	27.91
NT	24.42	18.13	23.80	18.84

Table 3. Summary of previous cropping history influence on soybean tillage trials conducted at the NMBES from 1978 to 1987.

Tillage practice	Previous crop grown on the land			
	Pasture	Ryegrass	Wheat	Soybeans
	bu grain/acre			
CT	21.80	35.31	31.90	29.35
NT	15.25	28.21	29.83	23.25

Table 4. Summary of row pattern influence on soybean tillage trials conducted at the NMBES from 1987 to 1993.

Tillage practices	Row Width	
	Wide rows (36-40 in)	Narrow rows (7-10 in)
	bu grain/acre	
CT	24.50	22.55
NT	19.35	22.20

Table 5. Summary of tillage trial performance in consecutive years of study.

Tillage practice	Years of study plots on same site			
	First year	Second year	Third year	Fifth year
	bu grain/acre			
CT	27.82	22.24	27.73	26.50
NT	21.63	20.33	26.53	28.00

Soil Strength for Deep-Tilled Wheat and Soybean Doublecrop in the Southeastern Coastal Plain

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Abstract

Deep tillage is needed to disrupt subsoil hardpans that form in many Coastal Plain soils. Some producers deep till before planting every crop, even when doublecropping. The purpose of this study was to find out whether fall tillage, spring tillage, or both were most beneficial for a wheat/soybean doublecropping system. We planted eight treatments in each of four replicates. Treatments were combinations of surface and deep tillage. Surface tillage treatments were disked and not disked. Each surface tillage was not deep tilled or paratilled before wheat planting, soybean planting, and both. Disked plots had a pan at the 4- to 6-inch depth, just below the disked zone, unless it was disrupted during deep tillage. Treatments with deep tillage at spring only and both spring and fall had 1 to 7 atm lower soil strengths than the fall only and no deep tillage treatments. Yields were 10 to 20 bu/A higher for the deep tilled treatments. Additional monitoring of soil strength and yield is needed to find more precise differences among treatments.

Introduction

Deep tillage is needed in many Coastal Plain soils to disrupt subsoil hardpans that restrict root growth. Annual deep tillage, usually subsoiling, is recommended at spring planting (Threadgill, 1982, Busscher et al., 1986). For the past 2 years, the Coastal Plain's acreage of doublecropped soybeans planted after small grains has grown from 239,000 acres in 1993, with 24% in reduced tillage, to 255,000 acres in 1994, with 30% in reduced tillage. Because planting early lengthens the soybean growing season and increases yield, soybean planting closely follows wheat harvest. To facilitate the early spring planting, some farmers subsoil in the fall. Others believe that they need to subsoil twice, before planting both soybeans and wheat.

It was our objective to determine whether subsoiling in the spring, in the fall, or both resulted in the greatest improvement in soybean and wheat yield and soil cone index. Our hypothesis was that a producer's choice of subsoil frequency and timing would affect crop production and cone index.

Methods

Wheat-soybean doublecropped plots were established in 1993 at the Pee Dee Research and Education Center near Florence, SC. The winter wheat cultivar grown was Northrup King 'Coker 9134,' a soft red winter wheat. The soybean grown was 'Haygood,' a Maturity Group VII cultivar. The soil was Rains (typic Paleaquult) with a hardpan below the plow layer. In the previous summer, the field had been planted in soybean.

We established two surface tillage and four deep tillage treatments. Surface tillage treatments were either not disked or disked twice before planting. Deep tillage treatments included paratilling at soybean planting, at wheat planting, at both soybean and wheat planting, or no paratilling. The eight treatments were arranged in a randomized complete block design and replicated four times. Each plot was 10 feet wide and 50 feet long.

Surface tillage, deep tillage, and planting were done in separate operations. We used the same wheel tracks as much as possible for all these operations and for harvesting. Surface tillage was done with a 10-foot wide Tufline disk (Tufline Mfg. Co., Columbus, GA) pulled by a John Deere 4230 100-HP (Deere and Co., Moline, IL) tractor with wheels on 64-inch centers. A four-shank paratill (Tye Co., Lockney, TX) was used to deep till to 16 inches. Shanks were spaced at 30 inches. The paratill was pulled with a Case 2670 (now Case-IH, Racine, WI) 220-HP 4-wheel drive tractor with dual wheels on 75-inch and 122-inch centers.

Both the wheat and the soybeans were drilled with a 10-foot wide John Deere 750 No-till Planter pulled by a Massey Ferguson (Massey Ferguson, Inc., Des Moines, IA) 398 80-HP tractor with wheels on 75-inch centers. Wheat harvesting was done with an Allis Chalmers F3 (now Deutz-Allis, Norcross, GA) Gleaner with a 13-foot wide header. The harvester had wheels on 8-foot centers.

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Wheat was drilled on Nov. 18, 1993 at a rate of 20 seedslft and harvested as whole plots on May 26, 1994. Soybeans were drilled on May 30, 1994 at a rate of 4 seeds/ft in 7.5-inch wide rows and harvested Nov. 14, 1994.

Soybean yield data were collected by hand from six 3-foot sections of rows near the center of the plot. Plot cleanup was done with an IH 1420 axial flow combine (now Case-IH, Racine, WI) with wheels on 7.5-foot centers and a 13-foot header. Yield data were corrected to 13% moisture for both wheat and soybeans.

Following soil test recommendations, 80 lb/A of both P and K were preplant broadcast onto all wheat plots. Ammonium nitrate was broadcast onto all plots at a rate of 30 lb N/A immediately after wheat planting and 50 lb N/A sidedressed March 8, 1994 (the stem erect wheat growth stage). Fertilizer was applied with a 10-foot wide Gandy spreader (Gandy Co., Owatonna, MN) pulled by the Massey Ferguson 298 tractor.

Nondisked plots were sprayed with Roundup@ (glyphosate) at a rate of 1 lb ai/A before wheat planting. Nondisked plots were sprayed with Bronco@ (alachlor plus glyphosate) at a rate of 3.5 lb ai/A before soybean planting. Lasso@ (alachlor) preemergence was applied to disked plots at a rate of 2.3 lb ai/A before soybean emergence.

To control annual broad leaves and nutsedge, Classic@ (chlorimuron) was applied to all plots at a rate of 0.012 lb ai/A 21 days after planting. To control annual grasses, Poast Plus@ (sethoxydim) was applied to all plots at a rate of 0.19 lb ai/A 30 days after planting.

Soil strength was measured with a 0.5-inch diameter, cone-tipped penetrometer (Carter, 1967). Strength was measured from the middle of the plot outward at intervals of 3.75 inches to a distance of 30 inches (the distance between paratill shanks) and to a depth of 22 inches. Data were digitized into the computer and log transformed according to the recommendation of Cassel and Nelson (1979) before analysis. Data for all positions across the plot and depth were combined to produce cross-sectional contours of soil cone indices for each plot using the method of Busscher et al. (1986).

We analyzed data using ANOVA in SAS (SAS Institute, 1990) and the least square difference procedure. Cone index data were analyzed using a split-split plot randomized complete block design. The first split was on position across the row and the second on depth. The 5% level of significance was used.

Results

General

Yields were taken for the winter wheat crop of 1993-1994 and the soybean crop of 1994 (Table 1). Soil cone indices shown below were from the spring soybean and fall wheat crops of 1994 (Table 2). Please, note for the sake of terminology, that spring tillage and fall tillage are deep-tillage treatments. Spring planting and fall planting are soybeans and wheat planting.

Table 1. Mean yields for 1993-94 wheat and 1994 soybeans.

Deep Tillage	Wheat Disked	Wheat Non-disked	Wheat Mean	Soybeans Disked	Soybeans Non-disked	Soybeans Mean
	bu/A					
Spring	—	—	—	73.4	86.8	80.1ab
Fall	66.0	66.1	66.1a*	63.8	77.2	70.5bc
Both	—	—	—	72.5	97.8	85.1a
None	59.2	53.1	56.2b	57.3	64.5	60.9c
Mean	62.6a	59.6b	66.7b	81.6a		

* Soybeans or wheat, surface or deep-tilled means with the same letter are not significantly different using the LSD separation procedure.

Table 2. Mean cone indices of for 1994 soybeans and 1994 wheat.

Deep Tillage	At soybean planting Disked	At soybean planting Non-disked	At soybean planting Mean	At wheat planting Disked	At wheat planting Non-disked	At wheat planting Mean
	Atm					
Spring	11.6	11.2	11.4c*	10.1	9.0	9.5b
Fall	18.4	15.3	16.8b	10.2	9.7	9.9b
Both	11.4	10.5	10.9c	9.3	8.9	9.1b
None	21.3	20.8	21.1a	15.0	14.4	14.8a
Mean	15.1a	14.0b	11.0a	10.3a		

* Soybeans or wheat, surface or deep-tilled means with the same letter are not significantly different using the LSD separation procedure.

Yield (Fall 1993 and Spring 1994)

For the wheat planted in 1993, yields were 3 bu/A higher for disked than for nondisked treatments (Table 1). This was probably a result of poorer stand in nondisked plots. For deep-tillage treatments, there was no difference between spring or no deep-tillage treatments and between fall or both deep-tillage treatments since they were the same treatments for this first crop. Fall deep-tillage treatments yielded significantly more (9.9 bu/A) than no deep-tillage treatments.

For the 1994 soybean, yields were 14.9 bu/a higher for non-disked than for disked treatments (Table 1). This could be at least partly a result of the 1.1- atm lower cone indices measured in nondisked treatments (Table 2). A trend is noticeable among the deep-tillage treatments. Treatments with most recent deep-tillage yielded most. Highest yield was for the treatment that had been deep tilled in both fall and spring, next highest was for the treatment deep tilled in spring, next was the fall deep-tilled treatment, and lowest was the treatment that had not been deep tilled (Table 1).

Cone Index (Spring 1994 and Fall 1994)

Mean profile soil cone indices are 1.1 atm higher for disked than for nondisked treatments for measurements taken at soybean planting (Table 2). Disked treatment cone indices were also higher but not significantly different for the measurements taken at wheat planting.

The surface tillage by depth interaction was significant for both the wheat and soybean planting. For the top 4 inches, the disked treatment had a lower cone index. Below that, its cone index was higher. For both wheat and soybean plantings, a tillage pan near the surface of the disked treatment with no deep tillage existed, while there was none (soil strength contours are further apart) for the nondisked treatments with no deep tillage. This is shown at soybean planting in Figure 1; contours for wheat planting are not shown.

Nondeep-tilled treatments had 4- to 10-atm higher cone indices than deep-tilled treatments. This was true for both wheat and soybean planting (Table 2). This difference can be seen in Figure 1 by the loosened zones of deep disruption for the deep-tilled treatments and higher, more uniform cone indices across the profiles of the treatments not deep tilled.

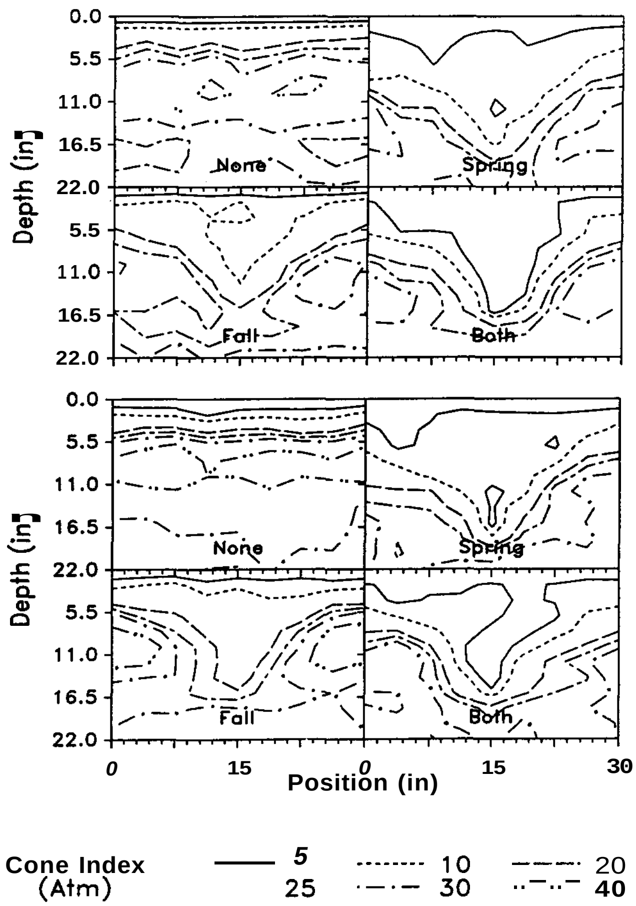

Figure 1. Soil strength contours for the soybean spring 1994 planting nondisked (top) and disked (bottom) treatments. The time of deep tillage is listed as none, spring, fall, or both (spring and fall).

Position across the plot and depth had significant interactions with deep tillage. The interaction of deep tillage by position can be seen by more uniform cone indices across the plots that were not deep tilled (Figure 1). Treatments with deep tillage had v-shaped or u-shaped zones of disruption to about the 16-inch depth caused by paratill shanks.

The interaction of deep tillage and depth can be seen in treatments that had no deep tillage as a pan at the 8- to 12-inch depths in both the wheat and soybean plantings. For deep-tilled plots, cone index generally increased with depth. An exception to this was in the cone indices taken at soybean (spring) planting for the fall-tilled plot. This treatment had maximum cone indices near the 10- to 15-inch depths. Busscher et al. (1986) similarly reported pan reformation over winter, especially in treatments with surface tillage. Mean profile cone indices were higher for the fall deep tillage than the spring or both spring and fall deep tillage (Table 2). Nevertheless, even in this treatment the subsoiled zone (contours not shown) was still evident.

Conclusion

Plots that were disked had a pan just below the disked zone. This pan was broken up during deep tillage. At both wheat and soybean planting the order of cone index was not-deep-tilled > fall-paratilled > spring-paratilled > fall-and-spring-paratilled. Yields were generally higher for the treatments with lower cone indices.

Preliminary results for this experiment indicate that less surface tillage and more deep tillage leads to lower overall soil profile cone indices and higher yields. It is not clear yet how the lower cone indices caused by tillage and higher yields inter act. Cone index, yield, and plant property monitoring will continue.

References

Busscher, W.J., R.E. Sojka, and C.W. Doty. 1986. Residual effects of tillage on Coastal Plain soil strength. Soil Sci. 141:144-148.

Carter, L.M. 1967. Portable penetrometer measures soil strength profiles. Agric. Eng. 48:348-349.

Cassel, D.K., and L.A. Nelson. 1979. Variability of mechanical impedence in a tilled one hectare field of Norfolk sandy loam. Soil Sci. Soc. Am. J. 43:450-455.

SAS Institute Inc. 1990. SAS/STAT User's Guide, Vol. 2, SAS. Inst. Inc., Carey, NC.

Threadgill, E.D. 1982. Residual tillage effects as determined by cone index. Trans. ASAE 25(4):859-863.

Assessing the Value of Pre-Plant and Post-Plant Tillage for Full-Season Soybeans on Clayey and Silt Loam Soils

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Abstract

Studies were conducted in 1992, 1993, and 1994 on Sharkey silty clay and Calloway-Loring-Henry silt loam soil. Pre-plant tillage consisted of disking once or twice with a finishing disk harrow and following this operation with a Do-All. Post-plant tillage consisted of plowing with a cultivator as necessary to control weeds or to break up soil crusting. The treatment design was 2 x 2 factorial with pre-plant tillage or no-till prior to planting and with post-plant tillage. No interaction was found between pre-plant and post-plant tillage. Neither pre-plant nor post-plant tillage affected the yield on Sharkey clay. Both pre-plant and post-plant tillage affected the yield on the Calloway-Loring-Henry silt loam during a dry growing season, pre-plant tillage having four times the effect of post-plant tillage. During a wet season, neither pre-plant nor post-plant tillage affected yields on the Calloway-Loring-Henry soil.

Introduction

Many experiments have been performed in which no-till production systems are contrasted with tilled systems. These production systems are compared in total usually to decide which are the most profitable. Compliance with the Farm Bill has also impacted on adaptation of reduced tillage. On soils that have a poor internal drainage or impermeable layers close to the surface (less than 22 inches deep), pre-plant tillage that produces a surface mulch may conserve soil moisture by preventing conductance to the soil surface and subsequent evaporation. This would be especially true in regions of the humid South. In the spring, soils such as those described above will have a profile that is full of water. It is conceivable that a surface mulch of dead plant debris could have the same moisture-conserving effect as pre-plant tillage. A similar moisture conservation scenario could also be operational after planting.

Other than moisture loss, soil compaction, infiltration, and aeration may be impacted by tillage. The infiltration rate of swelling clay or crusting silt loam soils may be increased dramatically by mechanical plowing or cultivation. Surface mulches also can be a contributing factor for increased infiltration (Langdale et al., 1994). Aeration is also a factor that may limit plant root growth and moisture uptake. Poor root growth could also be the result of soil density or compaction that can be ameliorated by tillage operations. The basic question of the value of pre-plant and post-plant tillage is difficult to address. The objective of the studies in this report was to assess the effect of conventional flat seedbed preparation and post-plant tillage on soybean production on a Sharkey silty clay and Loring-Calloway-Henry silt loam soil.

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Materials and Methods

Experiments were conducted in 1992, 1993, and 1994 at the Northeast Research and Extension Center ((NEREC), Keiser, AR; in 1992 and 1993 at Cotton Branch Experiment Station (CBES), Marianna, AR; and in 1994 at Pine Tree Experiment Station, (PTES) Colt, AR. Main plots were preplant tillage, and subplots were post-plant cultivation. Preplant tillage consisted of disking once or twice with a finishing disk and following the disking operation with a Do-All. Post-plant tillage consisted of cultivating as necessary to control weeds or break up soil crusts.

The treatment design was a 2 x 2 factorial of pre-plant (yes or no) and post-plant (yes or no) tillage. Selected cultural practices and site characteristics are described in Table 1.

Grain yields were adjusted to 13% moisture. Costs and profits were estimated using the Mississippi State University budget generator (Spurlock, 1992) and a soybean price of $6.02/bu. Component analysis for various crop inputs is obtained by using no-till as the base. The addition of a component is then calculated by averaging over all treatments where one tillage component is added to the system.

Results and Discussion

Yield results obtained from the duration of the study are presented in Table 2. It should be pointed out 1992 and 1994

Table 1. Selected site characteristics, cultural practices, and temporal log for tillage experiments at NEREC, Keiser; CBES, Marianna; and PTES, Colt.

	Soil Type	
	Sharkey[1] silty clay	**Loring-Calloway-Henry[2] silt loam**
Planting Date	(1) 6/24/92 (2) 5/26/93 (3) 5/23/94	(1) 6/18/92 (2) 5/27/93 (3) 5/19/94
Conventional Seedbed Preparation	(1) 6/24/92 (2) 5/26/93 (3) 5/20/94	(1) 6/16/92 (2) 5/27/93 (3) 5/19/94
Chemical Burndown[3]	(1) 6/24/92 (2) 5/26/93 (3) 5/20/94	(1) 6/16/92 (2) 5/29/93 (3) 5/19/94
Variety	1992 - Asgrow A5403 1993 - Pioneer P9592 1994 - Northrup King S5960	1992 - Asgrow A5403 1993 - Northrup King S5960 1994 - Northrup King S5960
Seeds/row-foot	3-5	3-5
Harvest Date	(1) 10/29/92 (2) 10/27/93 (3) 11/04/94	(1) 10/19/92 (2) 10/26/93 (3) 11/23/94

[1] 3 years same location NEREC, Mississippi County
[2] 2 years Lee County plus 1 year St. Francis County
[3] Burndown was with Roundup at 1.5 pt/A of 4.7 lb. ai/gal formulation.

were years of adequate moisture, and 1993 was an extremely dry growing season. Under dryland conditions, a significant pre-plant tillage-by-year interaction was found on the silt loam soil but no interaction was measured on the silty clay.

Three-year average economic returns for each treatment combination are presented in Table 3. Production costs generally increase as tillage inputs increase. However, profits are decreased with the increased tillage at NEREC on the silty clay soil.

A component analysis is presented in Table 4. It is informative to note the loss in profit associated with pre- and post-plant tillage at NEREC. These data strongly suggest that shallow pre-plant and post-plant tillage does not improve crop yields on clay soils. Shallow tillage operations may be desirable for surface smoothing, low-cost weed control, herbicide incorporation, etc., none of which are included in the scope of this study.

On a silt loam soil, pre-plant tillage usually was the most profitable practice, (Table 4). In 1993, an extremely dry year, one trip with a disk and Do-All increased profits dramatical-

Table 2. Pre- and post-plant tillage effects on soybean *grain* yield on Sharkey and Loring-Calloway-Henry soils.

		Tillage					
		Re-plant			Post-Plant		
Location	**Year**	**Yes**	**No**	**Diff.**	**Yes**	**No**	**Diff.**
		------------------- bu/A					
Sharkey silty clay	1992-94	48.1	48.9	0.8	48.4	48.7	0.3
Loring-	1992	30.0	28.1	1.9	30.2	28.0	2.2
Calloway-Henry	1993	26.8	15.9	10.9	22.6	20.0	2.6
silt loam	1994	37.2	36.6	0.6	36.7	37.0	−0.3
	1992-94	31.1	27.0	4.1	29.9	28.1	1.8

Table 3. Economic returns[1] based on 3-year average yield estimated for various tillage regimes for soybeans.

Tillage	**Replant**	Yes		No	
	Post-plant	**Yes**	**No**	**Yes**	No
		Sharkey silty clay			
Operating Cost[2]		$ 64.19	$ 61.58	$ 58.43	$ 56.55
Total Cost[3]		92.90	87.83	82.97	78.63
Profit[4]		$194.25	$202.95	$210.81	$217.13
		Loring-Calloway-Henry silt loam			
Operating Cost		$ 59.25	$ 56.33	$ 57.30	$ 57.16
Total Cost		87.86	82.30	80.97	78.20
Profit		$103.99	$102.69	$ 86.20	$ 77.89

[1] No charge was issued for land, risk, overhead labor, other overhead, crop insurance, real estate taxes, and management.
[2] Operating costs are taken from published crop production budgets with modifications to reflect changed production practices.
[3] Total costs are taken from published crop production budgets with modifications to reflect changed production practices.
[4] Profit computed as soybean yield times $6.02/bu minus total costs. This price selected as the average from 1981-1990 over the last 10 years for Arkansas.

ly, (Table 5). This indicates the importance of pre-plant tillage on these soils during dry, growing seasons. During the wet season of 1992 and 1994, tillage made no difference. Tillage could help stabilize yields on these soils. Additionally, in this study only 1 year in 3 was dry. If 3 years in 5 were droughty, then tillage could be even more profitable.

Acknowledgments

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Table 4. Component analysis1 for pre- and post-plant tillage operations for 3-year average yield.

	Yield bu	Operating Cost[2]	Total Cost[3]	Profit[4]
		---------------- $/A ----------------		
		Sharkey silty clay		
Base = No Tillage	49.1	56.55	78.63	217.13
Add Pre-plant Tillage	(0.8)	5.03	9.20	(14.20)
Add Post-plant Tillage	(0.6)	2.61	5.07	(8.68)
Add Both Pre- & Post-Plant Tillage	47.7	64.19	92.90	194.25
		Loring- Calloway-Henry silt loam		
Base = No Tillage	25.9	57.76	78.20	77.89
Add Pre-plant Tillage	1.2	2.92	5.36	1.30
Add Both Pre- & Post-Plant Tillage	31.9	59.25	87.86	103.99

[1] No charge was issued for land, risk, overhead labor, other overhead, crop insurance, real estate taxes, and management.

[2] Operating costs are taken from published crop production budgets with modifications to reflect changed production practices.

[3] Total costs are taken from published crop production budgets with modifications to reflect changed production budgets with modifications to reflect changed production practices.

[4] Profit computed as soybean yield times $6.02/bu minus total costs. This price selected as the average from 1981-1990 over the last 10 years for Arkansas.

Literature Cited

1. Langdale, G.W., E.E. Albert, R.R. Bruce, W.M. Edwards, and K.C. McGregor. 1994. Concepts of residue management: Infiltration, Run off and Erosion. *In* B.A. Stewart and J.L. Hatfield (eds.) Crop Residue Management. Adv. in Soil Sci. pp. 109-124.
2. Spurlock, **S.R.** 1992. Mississippi State. University budget generator. Miss. St. Univ. Agric. Econ. Tech. Publ. No. 88.

Table 5. Component analysis[1] for pre- and post-plant tillage operations.

	Loring-Calloway-Henry silt loam			
	Yield (bu)	Operating Cost[2]	Total Cost'	Profit[4]
Adequate Moisture Crop Year 1992				
Base No-Tillage	26.5	$ 52.74	$74.38	$ 85.15
Add Pre-plant Tillage	1.9	197	7.35	4.09
Add Post-plant Tillage	2.4	1.49	4.83	9.62
Add Both Pre- & Post-Plant Tillage	30.8	$56.20	$86.56	$ 98.86
Drought Crop Year 1993				
Base No-Tillage	13.7	$54.39	$74.34	$ 6.14
Add Pre-plant Tillage	11.0	(8.55)	(7.02)	83.46
Add Post-plant Tillage	2.7	(3.66)	(2.19)	(2.03)
Add Both Pre- & Post-Plant Tillage	21.4	$42.18	$67.13	$ 87.57
Adequate Moisture Crop Year 1994				
Base No-Tillage	37.6	$66.01	$85.83	$140.34
Add Pre-plant Tillage	(1.2)	(2.53)	1.52	(8.69)
Add Post-plant Tillage	1.5	1.89	3.13	6.02
Add Both Pre- & Post-Plant Tillage	37.9	$65.37	$90.48	$137.67

[1] No charge was issued for land, risk, overhead labor, other overhead, crop insurance, real estate taxes, and management.

[2] Operating costs are taken from published crop production budgets with modifications to reflect changed production practices.

[3] Total costs are taken from published crop production budgets with modifications to reflect changed production practices.

[4] Profit computed as soybean yield times $6.02/bu minus total costs. This price selected as the average from 1981-1990 over the last 10 years for Arkansas.

Estimation of N and P in Florida Dairy Wastewater for Silage Systems

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Abstract

Manure management is an integral concern of Florida dairymen. Wastewater from nine dairy sprayfields on seven north Florida dairies with overhead sprinkler or gun irrigation facilities was collected biweekly from early September 1992 to January 1993. Samples were taken from the pump area of either anaerobic lagoons or settling ponds, rainfall, and from effluent plus rainfall in sprayfields. All unfiltered and filtered samples were analyzed for total Kjeldahl N, NH_4^+, NO_3^-, and P. Concentrations of different forms of N and for P were site-specific, likely due to differences in wastewater and manure handling and disposal systems and herd sizes. Based on effluent analysis, dairies were applying large and differential amounts of solids through their irrigation systems to sprayfields. This was confirmed by filtered samples, accounting for only as much as 55% of the total Kjeldahl N in unfiltered samples for one dairy. Filtered NH_4^+ levels were 41% to 85% of total Kjeldahl in unfiltered samples. Based on literature, it was estimated that most dairies were under-fertilizing existing crops for N and applying slightly above or about the right amount of P. Essentially no nitrate was produced in dairy effluent that was applied to the sprayfields.

Introduction

Typical water use per 100 dairy cows per week is 122,500 gallons during the hot season in Florida (Van Horn, et al., 1993). Heightened environmental concerns and need for resource conservation have caused implementation of water use permits and other possible regulatory actions in many states. A theoretical balanced N cycle for a dairy was suggested by Van Horn et al. (1991). They proposed that over 80% of waste N was lost in some manure handling systems before reaching the crop in the field. The concentrations and ratios of nutrients in wastewater can affect forage growth and yield (Butler et al., 1986; Johnson et al., 1991). Excess application of wastewater has been shown to reduce growth and increase leaching of NO_3^- (Hubbard et al., 1986; Hubbard et al., 1987; Hubbard and Sheridan, 1989).

Multiple cropping forage system possibilities are numerous for dairy producers (Table 1) (Gallaher and Cummings, 1976; Gallaher, et al., 1991; Johnson, et al., 1991; Mitchell and Gallaher, 1979). A typical net return of $322/acre (30 ton silage per year) from doublecropped corn for silage was reported by Gallaher et al. (1991). If nutrients from wastewater were to provide nutrients for the corn silage crops instead of applying fertilizers, net return would increase to $536/acre, a net $214/acre increase.

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Choice of a dairy forage production system that produces high quality forage (Table 1) and best utilizes recycled nutrient wastewater would be dependent upon nutrient concentrations and ratios in the dairy wastewater. Nitrogen losses from soil in the form of ammonia (NH_3) can range from 20 to 90% of applied N (Hargrove, 1988). Under laboratory conditions, N losses in the form of NH_3 have been shown to be as great as 90% when N is applied to the surface of sandy soils with very low buffering capacity (Fenn and Hossner, 1985).

According to a summary from extension publications from several states (Killorn, 1993), nutrient contents of manure from dairy feedlots ranged from 17 lb N/ton in the summer months to 12 lb N/ton in winter months. For P, it was concluded that there was about 9 lb/ton in summer compared to 7 lb/ton in the winter. It was further estimated that only 25% of the total N applied in dairy fresh or liquid manure that was not soil-incorporated was available to growing crops in the year of application. The ammonium (NH_4^+) in dairy manure and wastewater is immediately available to plants. An average of about 50% of total N in animal manures was estimated to be in the ammonium form (Killorn, 1993). Van Horn et al., (1991) estimated 40 to 50% of total N was in the ammonium form for fresh excretions of manure for lactating dairy cows depending on diet. If manure and manure effluent is broadcast and is not incorporated into the soil the NH_3/NH_4^+ balance is more likely to shift in favor of greatly enhanced losses of N in the form of volatilized NH_3.

Table 1. Nitrogen and P removal by multiple cropping systems.

Location*	N	P	K	Crop 1	crop 2	Crop 3
	Nutrient			Multiple Cropping System		
	Pounds/acre			Winter	Spring/Summer	Summer/Fall
Georgia-I	262	31	246	Wheat	Corn	
Georgia-1	321	37	280	Wheat	Forage Sorghum	Forage Sorghum
Georgia-1	296	34	311	Wheat	Sudax	Sudax
Georgia-1	265	32	264	Rye	Corn	
Georgia-1	324	37	316	Rye	Forage Sorghum	Forage Sorghum
Georgia-1	323	38	347	Rye	Sudax	Sudax
Georgia-I	251	28	223	Oat	Corn	
Georgia-l	312	38	293	Oat	Forage Sorghum	Forage Sorghum
Georgia-I	280	33	311	Oat	Sudax	Sudax
Georgia-l	250	32	273	Barley	Corn	
Georgia-l	298	40	306	Barley	Forage Sorghum	Forage Sorghum
Georgia-I	321	37	358	Barley	Sudax	Sudax
Georgia-2	452	57	302	Rye	Corn	Bermudagrass
Florida-3	357	69	402	Wheat	Corn	Forage Sorghum
Florida-4	292	42	228	—	Corn	Corn
Florida-4	339	48	293	—	Corn	Sudax
Florida-4	319	45	231	—	Corn	Forage Sorghum
Florida-4	318	39	222	—	Forage Sorghum	Forage Sorghum
Florida-4	380	48	296	—	Sudax	Sudax

Georgia-I = Unpublished research data (average of 3 years) by R.N. Gallaher, Georgia Experiment Station, Experiment, GA, 1972-1975. Dry land management on a Cecil Sandy clay loam soil.

Georgia-2 = Data from Johnson, et al., 1991, Georgia Experiment Station, Tifton, GA. Study conducted under irrigation.

Florida-3 = Data from Mitchell and Gallaher, 1979. Sulfur fertilization of corn seedlings. Soil and Crop Sci. Sci. Soc. Fla. Proc. 39:40-44. Soil type was an Arredondo tine sand, experiment was irrigated.

Florida-4 = Data from Gallaher, et al., 1991, Florida Experiment Station, Gainesville, FL. Study conducted under irrigation.

Phosphorus availability the year of application of dairy manure and effluent is estimated to be about 70% (Killorn, 1993). The effect of application of P in manure and effluent should be monitored by a soil testing program.

The objectives of this research were: (a) to quantify N and P composition of dairy waste applied to sprayfields from anaerobic lagoon and liquid manure handling systems; (b) to identify changes, if any, in dairy wastewater composition of N and P over a 4-month period; and (c) to determine forms of N and amounts of N and P applied to sprayfields used to grow forages in multiple cropping systems.

Materials and Methods

All wastewater and rainwater samples were analyzed using standard analysis procedures (Clescari et al., 1989). Wastewaters from nine dairy spray fields with overhead sprinkler or gun irrigation facilities were collected biweekly from early September 1992 to January 1993 (Table 2). Dairy wastewater was soil-surface applied in sprayfields for all dairies in the study. Samples were taken from the pump area of lagoons and ponds, rainfall gauges, and from effluent plus rainfall collected in sprayfields. Large volume rain gauges were placed in two locations of each sprayfield for replicated samples. Concentrated H_2S0_4 was added to the rain gauges to ensure no losses of N received from the effluent that was

Table 2. Characteristics of seven Florida dairies, nine sprayfields, and manure handling, irrigation, and multiple cropping systems.

Florida County	Cows	Manure	Irrigation	Multiple cropping*
	System			
	(no.)			
Gilchrist West (GW)	1,640	Anaerobic lagoon Spread manure	Stationary Guns	W/C/C W/C/S
Gilchrist East (GE)	1,640	Anaerobic lagoon Spread manure	Center pivot W/C/S	W/C/C
Levy South (BP)	2,000	2 settling ponds	Center pivot (seven)	O+R/C/C R/C
Levy South (BC)	2,000	2 settling ponds	Center pivot (seven)	O+R/C/C RIC
Lafayette South (KB)	500	Anaerobic lagoon	Guns	R/BG
Levy North (AL)	2,500	3 settling ponds lagoon/spread	Center pivot	R/C/S R/C+PP;C/BG
Gilchrist South (WH)	2,500	anaerobic lagoon spread manure	Center pivot	F/C/S
Lafayette North (SHI)	500	pond/waste wash recycledlspreads	Center pivot	O/C/S O/PP
Suwannee (SHN)	450	Pond/lagoon spread manure	Gun	O/C/S O/C/C;O/BG

*O=oat; R=rye; C=corn; S=sorghum; PP=perennial peanut; BG=bermuda grass; F=winter small grain; W=wheat

Table 3. Amount and source of water collected in 4 months from nine sprayfields on seven north Florida dairies.

Dairv	Water Source		
	Effluent	Rainfall	Total
	Inches		
GW*	13.93	4.25	18.18
GE	10.29	4.25	14.54
BO	9.49	4.52	14.01
BC	5.16	1.35	6.51
KB	4.18	9.65	13.83
AL	2.66	8.80	11.46
WH	4.35	3.15	7.50
SHI	1.38	8.65	10.03
SHN	2.24	6.40	8.64

*See code identity in Table 2.

Table 4. Cumulative Kjeldahl N and forms of N and P in effluent plus rainfall collected in 4 months from nine sprayfields on seven north Florida dairies.

Dairy	Plant Nutrient Form and Type of Analysis					
	Unfiltered N	Filtered N	Filtered NH_4^+	Filtered NO_3^-	Unfiltered P	Filtered P
	Pounds/acre					
GW*	373**	206	153	1.14	60	57
GE	569	411	243	0.63	102	97
BO	329	306	183	0.48	73	111
BC	158	118	87	40.35	11	11
KB	209	133	111	6.30	32	11
AL	215	191	109	0.76	41	34
WH	113	104	76	19.07	16	18
SHI	164	138	92	2.20	33	38
SHN	55	53	46	0.22	17	24

*See code identity in Table 2.
**Amounts = total water received (Table 3); concentrations determined from rain gauges.

Table 5. Average Kjeldahl N and *forms* of N and P in pond effluent collected biweekly in 4 months from seven north Florida dairies.

Dairy	Plant Nutrient Form and Type of Analysis					
	Unfiltered N	Filtered N	Filtered NH_4^+	Filtered NO_3^-	Unfiltered P	Filtered P
	Pounds/acre					
GW*	38.7	15.0	10.3	0.04	7.7	1.8
GE	38.8	15.0	10.3	0.04	7.7	1.8
BO	33.4	27.1	15.8	0.01	7.4	3.9
BC	23.5	20.1	15.7	0.01	9.5	5.9
KB	46.7	37.2	27.0	0.01	7.8	0.7
AL	59.8	39.2	26.4	0.02	13.8	2.0
WH	29.4	22.3	17.5	0.01	6.1	3.3
SHI	73.3	42.5	44.1	0.01	16.3	2.1
SHN	30.2	25.5	15.0	0.02	7.1	2.3

*See code identity in Table 2.

sprayed on the field from one 2-week period to the next. Rain gauges were also used to collect data on rainfall.

All unfiltered and filtered samples were analyzed for total Kjeldahl N, and P using standard analysis procedures (Clescari et al., 1989). Total Kjeldahl N was analyzed using a semi-micro Kjeldahl digestion method (Gallaher, et al., 1976) followed by colorimetric determination with an autoanalyzer. A 30-mL portion of either unfiltered or filtered sample was placed into 100-mL digestion tubes along with 3.2 grams salt-catalyst (9:1 salt-catalyst ratio of anhydrous K_2SO_4:$CuSO_4$), and 10 mL of concentrated H_2SO_4. The water samples were evaporated slowly over several hours in an aluminum block digester at 150 °C then digested at 375 °C for a minimum of *2.5* hours (Gallaher, et al., 1975). Samples were cooled, vortexed while being diluted with deionized water, and brought to 75 mL volume at room temperature. Filtered samples were analyzed for NH_4^+ and NO_3^- concentrations using automated cadmium reduction and phenate processes, respectively (Alpkem Rapid Flow Analyzers).

Total P was determined on filtered samples by colorimetry. Total P was determined on unfiltered samples as follows: 100 mL of water was evaporated to dryness in pyrex beakers on a hotplate over several hours. Beakers were placed in a muffle furnace and ashed for a minimum of 8 hours. Upon cooling, 2 mL concentrated HC1 plus 20 mL of deionized water were added to each beaker and slowly evaporated to dryness on a hotplate. Upon cooling, *2* mL of concentrated HC1 plus 20 mL of deionized water were added to each beaker once more. A watch glass was placed over each beaker and samples were brought to a vigorous boil, removed from the hotplate and cooled. Each sample was washed into volumetric flask and brought to 100 mL volume. The same digestion procedure was conducted on the deionized water, HCl, and blank beakers to account for any possible contamination of P. These ashed samples were analyzed for P using colorimetry.

Results and Discussion

Effluent and rainwater received on the nine sprayfields ranged from 18.2 inches/acre to 6.5 inches/acre for GW and BC dairies, respectively for the 4-month period (Table 3). Total effluent received on sprayfields was highly positively related to the total N and NH_4^+ applied (Tables 4 and 5). Differences in unfiltered and filtered N analysis indicated that a significant amount of manure solids were applied through the irrigation systems (Table 4). In contrast to GW dairy, 93% and 89% of total N was in filtered samples compared to unfiltered for the BP and AL dairies, which indicated that these systems, which utilized settling ponds to separate manure, provided cleaner water for irrigation (Table 4).

The NH_4^+ ranged from *25%* to 85% of total unfiltered N applied to sprayfields (Table 4). Virtually no NO_3^- was applied to sprayfields from dairy wastewater (Table 4). The NO_3^- measured at the BC and WH dairies was due to fertilizer N injection into the center pivot irrigation system to supplement manure nutrients to meet crop needs. Nitrogen deficiency symptoms were evident in crops at both locations, requiring supplemental N fertilization. If we assume that only 25% of the total unfiltered Kjeldahl N was actually available to crops (Killorn, 1993), then N available for crop growth ranged from 142 lb N/acre/4 months to 14 lb N/acre/4 months (Table 4). These low levels of available N would not be sufficient to optimize crop growth for most forage crops over a 4-month period (Gallaher, et al., 1991).

The Kjeldahl N for filtered samples ranged from 39% to 86% of unfiltered samples indicating, as did field samples, that significant and differential quantities of solids were being applied on dairy sprayfields (Table 5). Large quantities of NH_4^+ were found in lagoons and ponds but almost no NO_3^- was found (Tables 5 and 6). Dairies, such as AL and SHI, reused lagoon and pond water for cleaning dairy facilities, which is the likely reason for higher levels of N in samples from these locations (Table 5). Based on the total effluent applied to sprayfields (Table 3) N estimates based on pond and lagoon effluent analysis were made (Tables 6, 7 and 8). Again, the results were extremely site-specific and compared somewhat favorably with field measurements for some dairies but not so well for others (Table 4).

Analysis of spray-field samples (Table 4, 7, and 8) and rainwater (Gallaher, et al., 1994) showed differential amounts of P received by crops. Rainwater P seemed to be high compared to what was reported in southern Florida (Anderson and Howell, 1993). Dust contamination likely occurred due to the 2-week periods between removal of rainfall from gauges.

Most of the P appeared to be associated with solids in the lagoon and pond samples (Tables 5, 6, and 7). Average P in filtered effluent ranged from 0.7 lb/acre-inch to 5.9 lb/acre-inch (Table 5) and was 9% to 69% of unfiltered P (Table 5), indicating high levels of solids in the effluent.

Based on effluent applied (Table 3), estimated P applied based on lagoon and pond analysis (Table 4) by some dairies would have been as much as 111 lb P/acre in a 4-month period. If 70% of this unfiltered P were available to growing crops (Killorn, 1993) then some dairies still applied slightly more P than typical forage crops would have required (Table 1) (Mitchell and Gallaher, 1979; Gallaher, et al., 1991). Most dairies applied 35 lb P/acre or less during this same period and would likely be adequately meeting the P requirements of most forage crops.

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Table 6 Predicted total Kjeldahl N and forms of N and P applied to nine sprayfields based on effluent collected and pond effluent analysis in 4 months from seven north Florida dairies.

	Plant Nutrient Form and Type of Analysis					
Dairy	Unfiltered N	Filtered N	Filtered NH_4+	Filtered NO_3^-	Unfiltered P	Filtered P
	Pounds/acre					
GW*	539**	209	144	0.56	107	25
GE	398	154	106	0.41	79	19
BO	317	257	150	0.10	70	37
BC	121	104	81	0.05	49	30
KB	195	156	113	0.04	33	3
AL	159	104	70	0.05	37	5
WH	128	97	76	0.04	27	14
SHI	102	59	61	0.01	23	3
SHN	68	57	34	0.05	16	5

*See code identity in Table 2.

** Amounts = Total water applications (Table 3) - concentrations determined in storage ponds.

Table 7. Nitrogen available in a 4-month period for crop utilization based on the N and P in filtered samples from samples collected in sprayfields and from pond analysis.

	N			P		
Dairy	Field	Pond	Average	Field	Pond	Average
	Pounds/acre					
GW*	51	52	52	40	18	29
GE	103	39	71	68	13	41
BP	76	64	70	78	26	52
BC	30	26	28	8	21	15
KB	33	39	36	8	2	5
AL	48	26	37	24	4	14
WH	26	24	25	13	10	12
SHI	35	15	25	27	2	15
SHN	13	14	14	17	4	12

*See code identity in Table 2. Nitrogen availability is based on an expected 75% losses due to volatilization and denitrification because the effluent was placed on the soil surface. P availability for immediate uptake is based on 70% of the P in filtered samples.

Table 8. Estimated N and P per month and 12 months based on 75% N losses and 70% P available from filtered samples taken over 4 months (Based on pond analysis).

	N		P	
Dairy	1 month	12 months	1 month	12 months
	Pounds/acre			
GW*	13	156	4.5	54
GE	10	120	3.3	40
BP	16	192	6.5	78
BC	7	84	5.3	64
KB	10	60	0.5	6
AL	7	84	1.0	12
WH	6	72	2.5	30
SHI	4	48	0.5	6
SHN	4	48	1.0	12

*See code identity in Table 2.

Literature Cited

Anderson, D.L., and M.D. Howell. 1993. Implementation of the Everglades surface water improvement and management plan in the EAA. Inter-American Sugar Cane Seminars, Miami, FL. 15-17 September. Univ. of Fla., Fla. Agric. Exp. Stn., Journal Series no. A-00248 9 pp.

Butler, J.L., J.C. Johnson, G.L. Newton, and R.K. Hubbard. 1986. Forage production system using dairy flush water. Amer. Soc. Agric. Eng. 86:1034.

Clescari, L.S., A.E. Greenburg, and R.R. Trussell, 1989. Standard methods for the examination of water and wastewater (17th edition). American Public Health Association-American Water Works Association-Water pollution Control Federation, Washington, DC.

Fenn, L.B., and L.R. Hossner. 1985. Ammonia volatilization from ammonium or ammonium-forming nitrogen fertilizers. *In* B.A. Stewart (ed.) Adv. Soil Sci. I:123-169.

Gallaher, R.N., C.O. Weldon, and J.G. Futral. 1975. An aluminum block digester for soil and plant analysis. Soil Sci. SOC. Amer. Proc. 39:803-806.

Gallaher, R.N., C.O. Weldon, and F.C. Boswell. 1976. A semi-automated procedure for total nitrogen in plant and soil samples. Soil Sci. Soc. Amer. J. 40:1887-889.

Gallaher, R.N., and D.G. Cummins. 1976. Year round forage production utilizing multiple cropping-minimum tillage management. Georgia Agr. Res. 17(3)l2-14.

Gallaher, R.N., S.A. Ford, R. McSorley, and J.M. Bennett. 1991. Corn forage and forage sorghum doublecropping yield, economics, crop nutrient removal and quality. Agron. Res. Report AY-91-05, Agron. Dept., IFAS, Univ. of Fla., Gainesville.

Gallaher, R.N., H.H. Van Horn, Jr., and T.A. Lang. 1994. Nitrogen and phosphorus in wastewater from nine sprayfields on seven north Florida dairies. Agron. Res. Report AY-94-01, Agron. Dept., IFAS, Univ. of Fla., Gainesville.

Hargrove, W.L. 1988. Evaluation of ammonia volatilization in the field. J. Prod. Agric. 1:104-111.

Hubbard, R.K., G.J. Gascho, J.E. Hook, and W.G. Knisel. 1986. Nitrate movement into shallow ground water through a Coastal Plain sand. Trans. of Amer. Soc. of Agric. Eng. 29:1564-1571.

Hubbard, R.K., D.L. Thomas, R.A. Leonard, and J.L. Butler. 1987. Surface runoff and shallow ground water quality as affected by center pivot applied dairy cattle wastes. Trans. Amer. Soc. Agric. Eng. 30:430-437.

Hubbard, R.K., and J.M Sheridan. 1989. Nitrate movement to groundwater in the southeastern Coastal Plain. J. Soil & Water Conserv. 44:20-27.

Johnson, J.C., G.L. Newton, and J.L. Butler. 1991. Recycling dairy waste to sustain annual triple crop production of forages. Proc. Florida Dairy Production Conf., Dairy Science Dept., Univ. of Fla. Coop. Ext., Gainesville.

Killorn, R. 1993. Crediting manure in Soil Fertility Programs. Solutions 37(2):32-35.

Mitchell, C.C., and R.N. Gallaher. 1979. Sulfur fertilization of corn seedlings. Soil and Crop Sci. Soc. of Fla. Proc. 39:40-44.

Van Horn, H.H., Jr., R.A. Nordstedt, A.V. Bottcher, E.A. Hanlon, D.A. Graetz, and C.F. Chambliss. 1991. Dairy manure management: Strategies for recycling nutrients to recover fertilizer value and avoid environmental pollution. Circular 1016. Fla. Coop. Extn. Serv., IFAS, Univ. of Fla., Gainesville, FL 32611.

VanHom, H.H., Jr., D.R. Bray, R.A. Nordstedt, R.A. Bucklin, A.B. Bottcher, R.N. Gallaher, C.G. Chambliss, and G. Kidder. 1993. Water budgets for Florida dairy farms. Circular 1091. Fla. Coop. Extn. Serv., IFAS, Univ. of Fla., Gainesville, FL 32611.

Manure As A Source of Leached Nitrate in Tilled and Untilled Soil

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Introduction

Application of manure to soils in crop production fields is strongly encouraged so that the nutrients in the manure will be utilized and the fecal organisms exposed to conditions adverse to their survival. Conservation tillage systems seek to maintain crop residues on the soil surface to reduce erosion. However, most manure management recommendations suggest immediate incorporation following surface applications in order to limit volatilization of ammonia (Lauer et al., 1976). Incorporation is also believed to reduce the potential for bacterial contamination of surface waters from field runoff (M. S. Coyne, personal communication).

Manure is a resource that may have the potential to cause degradation in subsurface water quality. No-tillage management is associated with the creation of stable "biopores" that can serve as conduits for dissolved materials (Edwards et al., 1992) and microorganisms (Smith et al., 1985) and which bypass much of the bulk soil's filtration potential. However, soils that are well drained often require no-tillage soil management to minimize further erosion and optimize summer crop performance. Such soils still have somewhat limited yield potential, especially during periods of drought. This reduced yield potential can contribute to greater residual soil nitrate levels at corn harvest. Macroporosity may result in there being less soil residence time for this residual nitrate prior to its being leached into shallow groundwater aquifers.

Groundwater nitrate contamination is generally thought to be associated with heavy manure/sludge use in Europe (Aslyng, 1986). Except where animal density is very high, the prevailing view in the United States has been that fertilizer nitrogen (N) represents a major source of the contamination (Papendick et al., 1987). Sims (1987) reported that poultry manure application was associated with less nitrate leaching than where equivalent amounts of fertilizer N were applied. Others have observed greater levels of nitrate in waters underlying manured sandy soils in the U. S. Coastal Plain (Hubbard et al., 1987; Weil et al., 1990).

No-till soils tend to be wetter early in the season and this may result in increased N loss via denitrification when manure is applied (Pratt et al., 1976), as well as greater N use due to raised crop yield potential. It remains unclear whether a greater yield potential will reduce the leaching of nitrate from manure-amended no-till soils, but differences in seasonal denitrification potential may have contributed to the observation that the seasonal timing of manure application has been found to be important in nitrate leaching in European studies (vanDijk, 1985; Bertilsson, 1988).

Studies combining tillage treatments with manure use have been few. The potential for conflict(s) between soil and manure management have not been defined. Once these conflicts are better described, soil erosion and manure management plans can be better integrated. The objectives of this research were: (1) to monitor the leaching of nitrate and determine its relationship, if any, to manure application timing, surface tillage, and fertilizer N use; and (2) to examine the tradeoffs between manure and fertilizer as sources of N in two conservation tillage soil management systems.

Methodology

The results to follow are for the 1993 cropping season, which begins with manure application in the fall of 1992 and continues through the 1993194 leaching season, which ends just prior to manure application in the spring of 1994. An existing (started in 1991) field research site established on a well-drained Maury silt loam (Typic Paleudalf) and located on the Spindletop Research Farm near Lexington, Kentucky, was used. The experimental design in place is a split-plot with three replications laid out in randomized blocks. Main plots consist of 12 tillage-manure timing treatments. Nitrogen rates of 0, 75, and 150 lb N/A make up the subplots. Subplot size is 12 feet (four rows) wide by 30 feet long. The cropping system is continuous corn *(Zea mays* L.), with a winter rye *(Secale cereale* L.) cover sown subsequent to corn harvest each year.

Six main plot treatments were used in this study. These tillage-manure timing treatments were (1) no-tillage, no manure; (2) no-tillage, fall manure every year; (3) no-tillage, spring manure every year; (4) no-tillage, fall and spring manure every year; (5) chisel plow and disking, no manure; and 6) chisel plow and disking, spring manure every year.

Tension-free "pan" lysimeters (Tyler and Thomas, 1977) were installed under undisturbed soil in two replicates of subplots chosen within the main plot (tillage-manure timing) treatments. Two experiments were put in place. In the first, to examine interactions between tillage, spring manure, and fertilizer N, the pans were installed in the 0 and 150 lb N/A subplots in main plot treatments 1, 3, 5, and 6 (see above).

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In the second, to observe effects due to the timing of manure application, pans were installed in the 0 lb N/A subplot of main plot treatments 1, 2, 3, and 4 (see above). Because of overlap between experiments of some subplots, only 20 pans were required. The pans were made from stainless steel and measured 3 feet wide (across the row) by 2 feet deep (along the row). Pans were installed such that the surface of the pan was 3 feet below the soil surface.

Water samples were collected and volumes measured following each rain event of sufficient intensity and/or duration to result in percolation. Samples were kept refrigerated at 4 "C until chemical analysis for nitrate (usually completed within 24 hours). Water data reported here are from April 15, 1993 until April 14, 1994. Due to the hydrologic cycle's impact on seasonal water flow, as well as the timing of field treatments, soil sampling, and crop growth, the water data were subdivided into four seasonal "periods." The four periods were: (I) April 15 to June 30, 1993 (early crop development); ((2) July 1 to Nov. 14, 1993 (late crop development/harvest); ((3) Nov. 15 to Dec. 31, 1993 (soil moisture recharge); and (4) January 1 to April 14, 1994 (soil moisture excess-drainage). Sampling events were combined within each period and the data pooled to give total water flux (in inches), volume weighted average nitrate concentration (in ppm N) and nitrate flux (in lb N/A) for each period.

Dairy *(Bos taurus)* manure applications (Dec. 9, 1992, May 10, 1993, and Nov. 24, 1993) were made by a tractor-pulled box-end spreader. To determine the rate of application, 20 to 24 flat trays, measuring 14 by 18 inches, were randomly assigned throughout the plots prior to spreading. After collection, the samples were dried on the trays, without heat, and then weighed, cleaned, and weighed again to determine the dry matter application rate. A subsample of manure was taken from each tray for chemical analysis and ground to pass a 0.5- mm screen opening.

Chisel plow tillage was done to a depth of 8 inches after the spring manure application (May 17, 1993) with twisted, 4 inches wide shovels on 1-foot centers. Secondary tillage consisted of disking twice (May 19, 1993). Pioneer 3279 corn was planted on May 21, 1993 at 23,100 seed/A at a row spacing of 3 feet using a John Deere 7000 Max-Emerge no-till corn planter equipped with row cleaners in front of double disc openers. Glyphosphate, atrazine, and alachlor were used for burndown and residual weed control. The nitrogen fertilizer treatments were broadcast top-dressed on June 25, 1993 using ammonium nitrate as the nitrogen source.

Corn yields were measured by hand harvesting 10 feet of each of the center two rows of each subplot on Oct. 15, 1993. Grain moisture was determined by weighing a random sample of five ears taken from each subplot, drying these ears at 60 °C for 1 week, weighing them again, shelling off the grain, and reweighing the grain. Yield data were corrected to a uniform 15.5% moisture. A subsample of grain was taken for chemical analysis. The grain subsamples were ground to pass a 0.5-mm screen opening.

Common winter rye was drilled over the entire plot area at a rate of 150 lb seed/A in 7-inch rows on Nov. 23, 1993 using a Lilliston 9680 no-till drill.

Soil sampling was performed before manure application in the spring (10 May 10, 1993 and April 20, 1994) and fall (Nov. 22, 1993) using a tractor-mounted hydraulic soil probe. Four cores (1.125-inch diameter), two between and two within the old corn rows, were taken and composited for each subplot. Samples were taken to a depth of 36 inches and divided into 0-6, 6-l2, 12-24 and 24-36-inch depth increments prior to compositing. Soil samples were air dried and crushed to pass a 2-mm screen opening. Soil bulk density was determined across the plot area, at each depth increment, using cores that did not exhibit any compression during sampling.

Manure and grain N concentrations were determined by microKjeldah1 digestion (Nelson and Sommers, 1973) with automated N detection by the colorimetric indophenol-blue reaction (Keeney and Nelson, 1982). Soil nitrate was found by extraction with molar KCL (25 mL so1ution:l0 g soil for 30 minutes), filtering the extract through Whatman 42 paper, and automated determination of nitrate by the colorimetric Greiss-Hosvay method (Keeney and Nelson, 1982) after reduction of nitrate to nitrite by Cd. Soil nitrate was expressed in lb N/A after correction of soil nitrate concentrations for the bulk density. Results were then summed across all the depth increments. Nitrate in water samples was determined using the same filtering and colorimetric procedures as for soil nitrate, above.

Statistical analyses of the measured variables were performed with the use of the Statistical Analysis System (SAS Institute, 1989). The General Linear Models (GLM) procedure was used for analysis of variance due to a few missing data. Means separation was performed using the Least Significant Difference (LSD) procedure. The experimental design of the first experiment (I) was a 2x2x2 factorial with split plots (2 tillage treatments by 2 manure rates by 2 fertilizer N rates). The experimental design of the second experiment (II) was a 2x2 factorial (yes or no fall manure vs. yes or no spring manure). There were two replications for water data and three replications for the crop and soil data.

Results and Discussion

Manure application rates were not consistent from one application date to the next (Table I). The December 1992 (fall) application was somewhat under the target rate of 5 tons dry

Table 1. Manure applications made during the study period.

Application Date	Application Rate of:		
	Dry Matter	Total N	Available N*
	lb/acre	---------- lb N/acre	----
Dec. 9, 1992 (fall)	8,800	195	98
May 10, 1993 (spring)	18,600	401	200
Nov. 24, 1993 (fall)	12,800	324	162

* Available N assumed to be one-half the total N in the year of application.

matter per acre, while the two later applications were over the target rate. The nitrogen contained in the manure was always greater than the highest fertilizer N rate used (150 lb N/A). The "available" N from the manure, calculated as half of that applied, was also greater than the highest fertilizer N rate, except for the December, 1992 application (Table 1).

Corn grain yields were generally quite good, but were unaffected by tillage in experiment I (Table 2). Grain N removal was similarly unaffected. There was an interaction between manure and fertilizer N use on corn grain yield and N removal in experiment I (Table 2). The spring manure application severely diminished the positive grain yield and N removal responses to fertilizer N. In the presence of manure, fertilizer N removal in corn grain (calculated by difference) was only 17 lb N/A, but was about 54 lb N/A in its absence. Grain removal of manure N was similarly affected by the use of fertilizer N.

In experiment II, there was a strong interaction between times of manure application (Table 2). While the fall manure application raised both grain yield and N removal in relation to the unamended control, spring manure application resulted in greater yield and N removal. Further, there was no benefit to fall manure when manure was also applied in the spring. This response pattern is due in part to a greater potential for N losses between manure application and corn planting.

Profile soil nitrate levels were generally higher where fertilizer N was used, especially under chisel plow soil management in experiment I (Table 3). Prior spring manure applications did not raise soil nitrate levels at this time. This was not the case for the more recent fall manure applications evaluated in experiment II, where mineralization resulted in greater soil nitrate in the spring of 1993 (Table 3).

After corn harvest, soil profile nitrate was still generally greater where fertilizer N was used, again especially after chisel plowing (Table 3). Spring manure applications raised soil profile nitrate levels only when no fertilizer N was used. Without manure use, fertilizer N application resulted in greater residual soil nitrate levels than did spring manure amendment without fertilizer. This occurred despite the fact that much more manure N was applied. Spring manure application also increased soil profile nitrate in experiment 11, but fall manure application did not (Table 3). Profile nitrate was generally greater after corn harvest than prior to corn planting. The fall manure treatments without fertilizer N in experiment II were the only treatments to evidence less profile nitrate at corn harvest than existed prior to corn planting. The gains in profile nitrate observed in other treatments between April and November 1993 were generally modest (1-14 lb NIA). The fraction of fertilizer and manure N accounted for in these changes in soil profile nitrate was generally small (less than 10%).

Apparent losses of nitrate from the soil profile between November 1993 and April 19994 were between 1 and 29 lb N/A in experiment I (Table 3). In experiment 11, plots receiving fall manure in November, 1993 (Table 1) evidenced gains of 12-14 lb N/A in profile nitrate over this period. In experiment I, fertilizer N treatments were less apparent in these data than in those of April 1993, but spring manure applications were more evident (Table 3).

Collected percolate was quite minimal during the cropping season, averaging 1.0 and 0.7 inch for the April 15 to June 30, 1993 and July 1 to Nov. 14, 1993 periods (1 and 2), respectively. More leachate was collected after crop harvest and over the winter, with the pans averaging 3.1 and 6.9 inches for the Nov. 15 to Dec. 31, 1993 and the Jan. 1 to

Table 2. Corn grain yields and nitrogen removal in 1993.

Tillage System	Manure Application Timing	Fertilizer N Rate	Grain Yield	Grain N Removal
		lb N/acre	bu/acre	lb N/acre
Experiment I: Main Effect of Tillage				
No-tillage			140.3a*	85.1a*
Chisel/disk			134.2a*	89.8a
Experiment I: Interaction of Manure and N Rate				
	none	0	89.3b*	43.3c*
		150	156.3a	97.1b
	spring only	0	149.7a	96.0b
		150	153.7a	113.3a
Experiment 11: Interaction Between Times of Manure Application				
–	none	0	89.6c*	42.8d*
All	fall only	0	116.6b	70.6c
No-till	spring only	0	145.4a	93.6a
–	fall + soring	0	137.5a	83.3b

*Means within a sub-column followed by the same letter are not significantly different at the 90% level of confidence by the LSD method.

Table 3. Soil profile (0 to 3 ft) nitrate prior to, and after, the 1993 growing season.

Tillage System	Manure Application Timing	Fertilizer N Rate	Soil Profile Nitrate: May 93	Nov. 93	April 94
		lb N/acre		lb N/acre	
Experiment I: Interaction of Tillage and N Rate					
No-tillage		0	5.1c*	10.4c*	8.3a*
		150	14.3b	24.1b	11.7a
Chisel/disk		0	5.3c*	11.3c	8.8a
		150	24.4a	37.5a	10.6a
Experiment I: Interaction of Manure and N Rate					
	None	0	4.5b*	6.0c*	5.0c*
		150	18.4a	30.6a	8.1bc
	Spring only	0	6.0b	15.6b	12.2ab
		150	20.3a	31.0a	14.1a
Experiment II: Interaction Between Times of Manure Application					
–	none	0	4.4b*	5.7b*	4.6c*
All	fall only	0	16.1a	9.1b	22.7a
No-till	spring only	0	9.1b	15.0a	12.9b
–	fall + spring	0	18.6a	16.9a	29.3a

*Means within a sub-column followed by the same letter are not significantly different at the 90% level of confidence by the LSD method.

April 14, 1994 periods (3 and 4), respectively. Percolate water quality, as affected by nitrate concentration, was not significantly impacted by choice of conservation tillage system in experiment I (Table 4). However, both spring manure application and fertilizer N use generally resulted in significantly greater concentrations of nitrate in leachate (Table 4). Except for the first period, fertilizer N generally raised water nitrate concentrations more than manure application. This observation supports a similar trend reported for profile soil nitrate levels (Table 3, above). Leachate nitrate concentrations tended to be lowest in the second period (Table 4), when the crop was most actively utilizing N. Leachate nitrate concentrations tended to be greatest in periods 3 and 4, when plant metabolism was lowest.

In experiment II, fall manure application significantly increased water nitrate concentrations in period 1, but not in other periods (Table 4). The fall plus spring manure application resulted in greater water nitrate concentrations than other treatments in period 2. No manure timing effects were observed in water nitrate concentrations in period 3, but spring manure applications resulted in generally greater water nitrate in period 4 (Table 4).

Quantities of leached nitrate were influenced by differences in water flux (data not shown) as well as differences in nitrate concentration. In experiment I, no-tillage generally resulted in less, and fertilizer N use more, nitrate flux (Table 5). Spring manure use had little effect on nitrate flux, primarily because water flux was reduced where spring manure was amended. In experiment II, there were also few differences in quantities of leached nitrate due to differences in the time of manure application. Nitrate leaching losses were generally small in periods 1 and 2, coincident with both greater water and nitrogen use by the growing crop.

In experiment I, nitrate leaching losses measured in water collected during periods 3 and 4 were generally greater than losses apparent due to changes in profile soil nitrate over the same period (Table 3). This suggests that some mineralization was generally occurring over the winter months. The rye cover crop would have been expected to have reversed the relationship between leached nitrate flux and apparent changes in soil nitrate over the same time period, but was ineffective as a nitrate scavenger because of late establishment and because of poor winter survival.

In summary, manure was as effective as fertilizer as a source of N in continuous corn culture. However, spring manure N resulted in less residual soil nitrate and lower concentrations of nitrate in leachate than did fertilizer N. At the rates used, there was little evidence for reduced N availability and greater N loss where a surface application of manure was used in combination with no-tillage. The data do suggest that spring manure applications will result in greater N use by the crop than will fall manure applications. Water quality was not improved commensurately, probably because of the much greater rate of manure applied in the spring, as compared to the fall, in this study. Fall manure application did result in greater levels of soil nitrate the following spring, indicating that some of the manure N was mineralized over the winter months. Water quality over the winter was well related to the disappearance of soil nitrate found after corn harvest, but leached nitrate generally exceeded apparent soil nitrate losses. Leached nitrate was generally small in relation to the amounts of manure and fertilizer N applied, suggesting that other N losslconversion pathways for nitrate are significant.

Table 4. Nitrate concentration of percolating water collected in the pan lysimeters.

Tillage System	Manure Application Timing	Fertilizer N Rate	Nitrate Conc. by Period: 1	2	3	4
		lb N/acre	ppm N			
Experiment I: Main Effect of Tillage						
No-tillage			6.2a*	4.9a*	10.la	13.la
Chisel/disk			7.7a	4.6a	7.6a	9.la
Experiment I: Main Effect of Manure						
	None		4.2b*	2.8b	7.3a	7.7b
	Spring only		9.8a	6.7a	10.4a	14.6a
Experiment I: Main Effect of N Rate						
		0	5.0b*	2.2b	4.9b	6.9b
		150	8.9a	7.3a	12.8a	15.3a
Experiment 11: Interaction Between Times of Manure Application						
—	None	0	3.4b*	2.5b	8.3a	6.1b
All	Fall only	0	10.2a	1.7b	4.4a	9.7ab
No-till	Spring only	0	5.3b	2.2b	5.2a	11.9ab
—	Fall + spring	0	12.8a	5.2a	5.8a	14.9a

* Means within a sub-column followed by the same letter are not significantly different at the 90% level of confidence by the LSD method.

Table 5. Quantity of nitrate-nitrogen leached into the pan lysimeters.

Tillage System	Manure Application Timing	Fertilizer N Rate	Leached Nitrate by Period: 1	2	3	4	total
		lb N/acre	lb N/acre				
Experiment I: Main Effect of Tillage							
No-tillage			1.4a*	0.5a	2.6b	10.9a	15.4b
Chisel/disk			2.3a	0.8a	8.3a	16.5a	27.7a
Experiment I: Main Effect of Manure							
	None		0.7a*	0.4a	5.5a	13.8a	20.3a
	Spring only		3.0a	0.9a	5.3a	13.6a	22.8a
Experiment I: Main Effect of N Rate							
		0	0.8a*	0.4b	2.9b	11.2a	15.3b
		150	2.8a	0.9a	8.0a	16.la	27.8a
Experiment II: Interaction Between Times of Manure Application							
—	None	0	O.la*	0.3a	2.2a	13.7c	16.3b
All	Fall only	0	3.3a	0.4a	3.7a	18.4b	25.8a
No-till	Spring only	0	1.5a	0.6a	4.6a	20.4ab	27.la
—	fall + spring	0	3.2a	1.0a	2.0a	23.0a	29.la

* Means within a sub-column followed by the same letter are not significantly different at the 90% level of confidence by the LSD method.

Literature Cited

Aslyng, H.C. 1986. Nitrogen balance in crop production and groundwater quality. p. 291-301 *In* Agricultural water management. A.L.M. vanWijk, J. Wesseling (eds). A.A. Balkema. Rotterdam, Netherlands.

Bertilsson, G. 1988. Lysimeter studies of nitrogen leaching and nitrogen balances as affected by agricultural practices. *Acta* Agr. Scandin. 38:3-11.

Edwards, W.M., M.J. Shipitalo, W.A. Dick, and L.B. Owens. 1992. Rainfall intensity affects transport of water and chemicals through macropores in no-till soil. Soil Sci. Soc. Am. J. 56:52.58.

Hubbard, R.K., D.L. Thomas, R.A. Leonard, and J.L. Butler. 1987. Surface runoff and shallow ground water quality as affected by center pivot applied dairy cattle wastes. Trans. ASAE 30:430-437.

Keeney, D.R., and D.W. Nelson. 1982. Nitrogen: inorganic forms. *In* A.L. Page et al. (eds.) Methods of Soil Analysis, 2nd *ed.* Agronomy 9:643.698.

Lauer, D.A., D.R. Bouldin, and S.D. Klausner. 1976. Ammonia volatilization from dairy manure spread on the soil surface. J. Environ. Qual. 5:134-141.

Nelson, D.W., and L.E. Sommers. 1973. Determination of total nitrogen in plant material. Agron. J. 65:109-112.

Papendick, R.I., L.F. Elliott, and J.F. Power. 1987. Alternative production systems to reduce nitrates in ground water. Am. J Altern. Agric. 2:19-24.

Pratt, P.F., S. Davis, and R.G. Sharpless. 1976. A four-year trial with animal manures. Hilgardia 44:99-125.

SAS Institute, Inc. 1989. SAS User's Guide: statistics version 6. SAS Institute, Inc., Cary, NC.

Sims, J.T. 1987. Agronomic evaluation of poultry manure as a nitrogen source for conventional and no-tillage corn. Agron. J. 79:563-570.

Smith, M.S., G.W. Thomas, R.E. White, and D. Ritonga. 1985. Transport of *Escherichia coli* through intact and disturbed soil columns. J. Environ. Qual. 14:87-91.

Tyler, D.D., and G.W. Thomas. 1977. Lysimeter measurements of nitrate and chloride losses from soil under conventional and no-tillage corn. J. Environ. Qual. 6:63-66.

vanDijk, T.A. 1985. Leaching of plant nutrients from arable land as affected by annual applications of cattle slurry. Report of an 8-year lysimeter experiment. Rapport, Inst. voor Bodemvrucht. No 2-85. 61pp.

Weil, R.R., R.A. Weismiller, and R.S. Turner. 1990. Nitrate contamination of groundwater under irrigated Coastal Plain soils. J. Environ. Qual. 19:441-448.

Fertilizer Nitrogen Management in Drill-Seeded, Stale Seedbed Rice

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Abstract

Conservation tillage practices are being adapted to rice production systems in Louisiana. This relatively new concept in rice is raising questions concerning nitrogen (N) fertilizer management and whether current recommendations in conventional systems are adequate for stale seedbed systems. A study was conducted on a Crowley silt loam soil (fine, montmorillonitic, thermic Typic Albaqualf) to determine if N behaves differently in conventional and stale seedbeds. Four rice varieties were drill-seeded each year into conventional and stale seedbeds and fertilized with 90, 120, 150, and 180 lb N/A prior to permanent flood establishment. The 150-lb N rate was also applied in a two-way split consisting of 100 lb N preflood (PF) and 50 lb N at midseason. A significant interaction occurred between varieties and tillage for days to 50% heading each year. Maturity of Lacassine and Cypress was decreased in the stale seedbed in 1993 and was increased in 1994. The other varieties were not affected.

A significant N-by-tillage interaction occurred in 1994 for plant heights. The plant heights increased as N increased in the conventional seedbed only. The plant height of Bengal responded to increasing N in the stale seedbed. There was no yield response to N in 1993. A significant variety-by-N interaction occurred for yield in 1994. Jodon yields increased as N increased to 150 lb/A. There was no response to increasing **N** by the other varieties. A significant variety-by-tillage interaction occurred each year. In 1993, yields of all varieties except Lacassine were reduced in the stale seedbed. In 1994, the yield of Lacassine was significantly reduced and that of Jodon increased in the stale bed while yield of Bengal was not affected by tillage. Tillage effect was not significant either year, and there was no interaction between tillage and N. These results indicate that current recommended rates of N for these varieties are appropriate for use in stale seedbed, drill-seeded systems.

Introduction

Concern about agriculture's impact on the environment has led to adoption of cultural practices that conserve soil, water, and nutrients. Stale seedbed cropping systems have become very popular in the United States. These innovative techniques are being adapted for use in many rice-producing areas, especially in Louisiana where surface waters are being affected by rice field effluent (Feagley et al., 1992; Feagley et al., 1993). Recommended agronomic practices established in conventionally tilled rice are being examined to determine if these practices need to be modified to better address the needs of stale seedbed cultural systems. Nitrogen management in drill-seeded rice is well established in the southern U.S. In Louisiana, all or most of the required N is applied PF at the 4-leaf growth stage (LSU Agricultural Center, 1987). Conventional seedbeds are very mellow and permeable to the floodwater at this time. Permanent flood establishment provides adequate incorporation of surface-applied N below the soil-water interface. Nitrogen is stabilized in the NH_4^+ form below the thin, oxidized layer and remains available to the developing rice.

Most stale seedbeds are more compacted prior to permanently flooding and downward mobility of N could be compromised. The presence of decomposing preplant vegetation could also influence the availability and utilization of surface-applied N. The objectives of this study were to (1) evaluate the performance of different rice varieties in conventional and stale seedbeds and (2) determine if there is a differential response to N when rice is grown in conventional and stale seedbed cultures.

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Materials and Methods

A tillage-by-variety-by-N experiment was conducted at the South Unit of the Rice Research Station, Crowley, LA, in 1993-94. Fertilizer (0 N-40 P_2O_5-40 K_2O was incorporated in the fall preceding each year of the experiment, and all land preparation required to establish a finished seedbed was also performed. The following spring, preplant vegetation was terminated with glyphosate (1.0 lb ai/A + 0.25% surfactant) 5 and 23 days preplant in 1993 and 1994, respectively. Conventionally tilled seedbeds were prepared within 3 to 5 days of planting. Lacassine, Cypress, Bengal, and Maybelle were seeded at 100 lb/A to a shallow depth in 7- by 25-foot plots (12 drill rows with 7-inch spacing) in 1993. Jodon was substituted for Maybelle in 1994. The experiment was periodically flushed to provide adequate moisture and to encourage stand development. Urea-N was applied at rates of 90, 120, 150, and 180 lb/A at the 4-leaf stage. The 150 lb/A rate was also applied in a two-way split consisting of 100 lb/A PF and 50 lb/A at midseason. Maturity (measured in days to 50% heading), plant height, and grain yield were determined.

The experiment was analyzed as a randomized complete block with a split plot arrangement of treatments and four replications. Tillage was assigned to the main plot and a factorial arrangement of varieties and N rates to the subplots. Results will be discussed by year since varieties were not consistent with respect to year.

Results and Discussion

Tillage had no influence on days to 50% heading in 1993

Table 1. Influence of tillage and N rate on performance and grain yield of drill-seeded rice varieties. Rice Research Station, South Unit, Crowley, LA. 1993.

Varietv	N[1] rate	Days to 50% heading: Conv	Days to 50% heading: No-till	Plant height: Conv	Plant height: No-till	Grain yield at 12% moisture: Conv	Grain yield at 12% moisture: No-till
				(cm)	(cm)	(lb/A)	(lb/A)
Lacassine	90	93	88	89	86	6,314	6,759
Lacassine	120	93	88	87	89	6,562	6,799
Lacassine	150	93	90	89	92	6,886	6,694
Lacassine	100|50	92	89	88	84	6,728	6,503
Lacassine	180	92	91	94	90	6,980	6,686
Cypress	90	91	89	91	90	7,614	7,107
Cypress	120	92	88	94	89	8,161	7,367
Cypress	150	94	90	97	93	7,586	7,365
Cypress	100|50	94	90	93	91	7,392	7,064
Cypress	180	94	90	94	94	7,437	7,191
Bengal	90	87	87	89	85	8,129	7,731
Bengal	120	87	86	90	85	8,258	8,143
Bengal	150	87	87	88	87	8,392	8,205
Bengal	100|50	88	87	89	86	8,392	7,992
Bengal	180	88	87	93	88	8,333	7,910
Maybelle	90	79	80	100	95	7,284	6,124
Maybelle	120	79	79	97	99	7,124	6,547
Maybelle	150	81	79	102	99	7,465	6,650
Maybelle	100150	80	78	97	99	7,462	6,609
Maybelle	180	80	80	100	96	7,713	6,648
Tillage (T) mean		88	86	93	91	7.511	7,105
C.V., %		1.84		4.26		7.27	
LSD (0.05):[2]							
Tillage		ns		1		ns	
Nitrogen (N) mean							
90		87		91		7,133	
120		87		91		7,370	
150		88		93		7,405	
100150		88		94		7,362	
180		88		91		7,268	
LSD (0.05):		1		2		ns	
Variety (V) mean							
Lacassine		91		89		6,691	
Cypress		91		93		7,428	
Bengal		87		88		8,148	
Maybelle		80		99		6,963	
LSD (0.05):		1		2		235	
Main effect interactions[z]							
V x N		ns		ns		ns	
V x T		*		ns		*	
N x T		ns		ns		ns	
V x N x T		ns		ns		ns	

[1] Two-way application of 150 lb N/A applied as 100 lb preflood and 50 lb at panicle initiation.

[2] *Denotes significance at P = 0.05; ns = nonsignificant.

(Table 1). Higher N resulted in a modest increase in days to 50% heading. Bengal and Maybelle matured 4 and 11 days earlier than Lacassine and Cypress, respectively. A significant variety-by-tillage interaction resulted in decreased days to 50% heading for Lacassine and Cypress when planted in a stale seedbed. Tillage had no effect on maturity of Bengal and Maybelle. Plant heights of all varieties increased with increasing N, and Cypress and Maybelle were significantly taller than Lacassine and Bengal. There was no varietal response to N but yield potential of the varieties was significantly different, and yields were in the order of Bengal > Cypress > Maybelle > Lacassine. The interaction between varieties and tillage was significant, with all varieties except Lacassine yielding lower in the stale seedbed. Tillage had no effect on Lacassine yield, but yield was significantly lower than the other varieties. Results from 1994 are presented in Table 2. Maturity response due to tillage, variety, and fertilizer was similar to that measured in 1993. Tillage had no effect and increasing rate of N had a small influence. Maturity of varieties over all tillage and N rates was significantly

Table 2. Influence of tillage and N rate on performance and grain yield of drill-seeded rice varieties. Rice Research Station, South Unit, Crowley, LA. 1994.

Variety	N[1] rate	Days to 50% heading		Plant height		Grain yield at 12% moisture	
		Conv	No-till	Conv	No-till	Conv	No-till
				(cm)		(lb/A)	
Lacassine	90	88	91	92	86	7,284	5,976
Lacassine	120	89	92	93	85	7,187	6,239
Lacassine	150	90	92	92	93	7,145	6,280
Lacassine	100150	89	90	88	86	6,866	6,393
Lacassine	180	90	93	94	87	7,381	6,584
Cypress	90	85	86	94	91	7,929	7,616
Cypress	120	85	87	96	90	8,122	7,501
Cypress	150	88	89	95	92	7,921	7,524
Cypress	100150	85	86	96	92	7,974	7,754
Cypress	180	87	88	97	95	7,821	7,863
Bengal	90	82	82	93	87	7,339	7,073
Bengal	120	83	83	94	89	7,421	6,945
Bengal	150	84	84	92	92	7,493	7,475
Bengal	100150	82	82	91	89	7,259	7,066
Bengal	180	84	84	96	91	7,302	7,401
Jodon	90	83	83	92	90	5,744	6,273
Jodon	120	84	84	96	89	7,165	6,729
Jodon	150	84	84	98	92	7,521	7,485
Jodon	100150	83	85	93	92	5,781	6,466
Jodon	180	84	84	98	95	7,058	8,105
Tillage (T) mean		86	86	94	90	7.286	7,037
C.V., %		1.51		3.51		8.69	
LSD (0.05):[2]							
Tillage		ns		2		ns	
Nitrogen (N) mean							
90		85		91		6,904	
120		86		92		7,164	
150		87		93		7,355	
100150		86		91		6,945	
180		87		94		7,439	
LSD (0.05):		1		2		308	
Variety (V) mean							
Lacassine		90		90		6,733	
Cypress		87		94		7,802	
Bengal		83		92		7,277	
Jodon		84		94		6,833	
LSD (0.05):		1		1		276	
Main effect interactions[2]							
V x N		ns		ns		*	
V x T		*		ns		*	
N x T		ns		*		ns	
V x N x T		ns		ns		ns	

[1] Two-way application of 150 lb N/A applied as 100 lb preflood and 50 lb at panicle initiation.
[2] * Denotes significance at P = 0.05; ns = nonsignificant.

different. Delayed maturity of Lacassine, probably caused by poor stand establishment, caused a significant variety-by-tillage interaction. Tillage had no influence on the other varieties. Cypress and Jodon were significantly taller than Lacassine and Bengal. The interaction between N and tillage was significant for plant height. The plant height of Jodon increased with increasing N in both seedbeds, Bengal and Lacassine plant heights were increased in the stale seedbed, and tillage had no effect on plant height of Cypress. The interactions between varieties and N and varieties and tillage were also significant for yield. Jodon responded to increasing N up to 150lb/A, and yield was decreased significantly at the highest rate of N. There was no yield response to increasing N for the other varieties. At the 150 lb/A rate of N, there was no difference in response to applying this amount in a single or two-way split application for any variety. The yield of Bengal was not affected by tillage method, and yield of Cypress was only slightly reduced in the stale seedbed. Yield of Jodon was decreased in the conventional seedbed and was probably due to straighthead, a physiological disorder. Straighthead was not as severe in the stale seedbed. A significant yield reduction occurred with Lacassine in the stale seedbed. Slow seedling growth and poor stand establishment contributed to the lower yield.

Summary

This experiment was conducted to evaluate the performance of rice varieties grown in conventional and stale seedbeds and to determine if N management should be tailored to the tillage system. Significant differences in maturity, plant height, and grain yield among varieties are typical of variety-by-N experiments. Variety-by-tillage interactions each year also indicate the potential for some varieties to be better suited for stale seedbed production. Since there was no interaction between N and tillage either year, there is no evidence to support a change in N management. Recommendations previously established in conventional tillage systems are also appropriate for use in stale seedbeds.

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Literature Review

Feagley, S.E., G.C. Sigua, R.L. Bengtson, P.K. Bollich, and S.D. Linscombe. 1992. Effects of different management practices on surface water quality from rice fields in southwest Louisiana. Journal of Plant Nutrition 15(8):1305-1321.

Feagley, S.E., G.C. Sigua, R.L. Bengtson, P.K. Bollich, and S.D. Linscombe. 1993. Effects of management practices on surface water quality from rice fields. Louisiana Agriculture, 36(1):8-10.

LSU Agricultural Center. 1987. Rice Production Handbook. La. Coop. Ext. Serv. and La. Agri. Exp. Stn. Pub. 2231. 63 pp.

Influence of Herbicide-Desiccated Cover Crops on Biological Soil Quality in the Mississippi Delta

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Abstract

The effect of crop residue management (CRM) systems on selected biological properties (microbial biomass/populations and soil enzyme activity) of Dundee soils under two cropping systems was investigated. In a cotton *(Gossypium hirsutum* L.) study, the influence of conventional tillage (CT) and no-tillage (NT) with and without an annual ryegrass cover crop *(Lolium multiforum* Lam.) on these properties was determined. Annual ryegrass residues in cotton stimulated total and Gram-negative bacteria, fluorescent pseudomonads, and total fungi for all sampling periods under both tillage systems. Soil aryl acylamidase, esterase, and phosphatase activity were greatest in the NT-ryegrass treatment. The second study addressed the effects of rye *(Secale cereale* L.) and hairy vetch *(Vicia villosa* Roth) cover crops in soybean [Glycine max (L.) Merr.]. The presence of cover crops initially enhanced total and Gram-negative bacteria, fluorescent pseudomonads, and microbial biomass N in Dundee surface soils (0-2 cm), with hairy vetch having the greatest effect. Both cover crops in soybeans enhanced surface soil esterase and phosphatase activities for the first **21** days after planting, with hairy vetch initially enhancing activity more than rye. Soils with cover crop had consistently higher sulfatase activity than soils in the bare ground control. In both studies, use of herbicide-desiccated cover crops enhanced microbial biomass/populations and soil enzyme activity, thereby improving soil quality.

Introduction

The use of CRM as a tool to improve soil quality is not a new concept. However, as national attention to sustainable agriculture continues to grow, increasing numbers of farmers are considering and adopting CRM systems. Cover crops used as green manure have been a component of southern farming systems. Recent attention has focused on direct seeding of crops into soils with herbicide-desiccated cover crops or planting into residues of the previous crop (e.g. soybean-wheat doublecrop).

Several reports have shown that cover crop residues remaining on the soil surface can provide weed control and minimize soil erosion (Liebl et al., 1992). Herbicide-desiccated cover crops may impact microbial activity. Since microorganisms play a considerable role in soil processes that directly affect soil quality (Paul and Clark, 1989), the effect of this approach to CRM on parameters of biological soil quality in the Mississippi Delta warranted investigation.

We investigated the effect of cover crops on microbial population dynamics, microbial biomass, and soil enzyme activities in cotton and soybean production systems, both very important in Mississipppi agriculture.

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Materials and Methods

A randomized complete block (4 replicates) cotton study was established in 1990 near Stoneville, Mississippi, with plots maintained in NT and CT. In the fall of 1993, a split-block (10-m by 12-m subplots) arrangement of treatments with the presence or absence of annual ryegrass was imposed on the study. All plots were treated with 1.1 kg/ha glyphosate one month prior to planting cotton the following spring. CT treatments were subsoiled and then disked twice; beds were prepared 2 weeks prior to planting and cultivated three times. Soils from two depths (0-2 and 2-10 cm) collected at planting and at 2, 5, and 8 weeks after planting were assessed for microbial populations and enzyme activities.

The soybean cover crop study was established in fall 1993. Three treatments [RCB design of four replicates] consisted of tilled bare ground (BG); and untilled soil with rye (RC) and hairy vetch (VC) cover crops. All plots were treated with 1.1 kg/ha paraquat at soybean planting, and received no additional herbicides during this study. Soils and cover crop residues were collected at soybean planting and at 3, 6, and 11 weeks after planting.

Moist soils were sieved through a #6 sieve and stored at 4 "C until microbial assays could be performed. Microbial populations were estimated by serial dilution spiral plating. Soils were diluted in 0.1 M phosphate buffer (pH 7.0) and plated on 10% tryptic soy agar (TSA) for total bacteria, TSA with 2 g/mL crystal violet for Gram-negative bacteria, and S-1 agar for fluorescent pseudomonads (Gould et al., 1985).

Fungi were enumerated on rose bengal potato dextrose agar with streptomycin (Martin, 1950). Esterase activity was determined using the fluorescein diacetate (FDA) hydrolysis method of Schunrer and Roswall (l982). Phosphatase and sulfatase activities were determined by colorimetric methods using nitrophenyl phosphate and sulfate, respectively, as substrates (Tabatabai, 1982). Aryl acylamidase activity was determined in cotton soils using 2-nitroacetanilide as substrate (Zablotowicz et al., 1995). Microbial biomass N was determined by chloroform fumigation, K_2SO_4 extraction, and ninhydrin reaction as described by Joergensen and Brookes (1990).

Results and Discussion

In the cotton study, annual ryegrass residues in both CT and NT significantly enhanced all measured microbial populations (Table 1). Stimulation of soil microorganisms was more persistent in the surface soil (0-2 cm) in NT- ryegrass, while greater microbial populations were observed in the 2-10 cm depth of CT-ryegrass plots. Increased total soil bacterial populations were specifically due to the proliferation of Gram-negative bacteria, such as fluorescent pseudomonads.

In the soybean cover crop study, both rye and vetch cover crops stimulated soil bacterial populations in the surface soil (0-2 cm) (Table 2). However, the effect of cover crop was significant only for the first 3 weeks after planting. The greatest stimulatory effects were observed in VC plots, where significantly greater bacterial populations were initially observed. Total bacteria and pseudomonad populations were significantly greater in surface soils of RC plots than in those of BG plots. Bacterial populations in cover crop residues were 50- to 1,000-fold greater than in the underlying soils in all samples taken from both the cotton and soybean studies (Table 3, only data at planting are shown).

In the soybean study, surface soils from VC and RC plots exhibited significantly greater microbial biomass than did those from BG plots (Table 2). Soils from VC plots initially had the greatest microbial biomass; however, the soils in RC maintained higher levels of microbial biomass than did soils in BG plots in later samplings. In the cotton study, microbial biomass in the surface soil from NT-ryegrass plots was significantly greater than in the surface soil from the other treatments at planting (2 09, 109, 91, and 60 g microbial biomass N/g soil for NT-ryegrass, NT-bare, CT-ryegrass, and CT-bare, respectively).

Following 4 years of NT, organic carbon content of the surface 0-2 cm of soil was 74-108% greater than the corresponding CT soils in the cotton study. The effect of cover crop on soil organic carbon was not significant in the first year of the soybean study (Table 4).

Adoption of practices that increase soil organic matter accumulation affects soil microorganisms. Long-term NT soils cropped with corn in several locations across the United States had populations of aerobic bacteria, facultative anaerobes, nitrite oxidizers, and fungi that were higher than those found in soils under CT (Doran, 1980). Only slight increases in microbial populations were observed after 4 years of NT in

Table 1. Effect of tillage and annual ryegrass cover crop on microbial populations of a Dundee silt loam, cotton study, 1994.

Tillage	Total Bacteria*		Gram Negative Bacteria[z]		Fluorescent Pseudomonads[2]		Total Fungi[2]	
Cover Crop'	0-2 cm	2-10 cm	0-2 cm	2-10 cm	0-2 cm	2-10 cm	0-2 cm	2-10 cm
Week 0								
NT-ryegrass	8.16 a[3]	7.92 b	6.68 a	6.70 b	6.27 a	6.12 b	5.25 a	4.95 a
CT-ryegrass	8.17 a	8.17 a	7.03 a	7.09 a	6.58 a	6.76 a	4.94 a	4.90 a
NT-bare	7.71 b	7.42 c	6.12 b	6.05 c	5.46 b	5.41 c	4.29 b	3.86 b
CT-bare	7.66 b	7.46 c	5.78 b	5.73 d	4.96 b	5.28 c	3.87 b	3.78 b
Week 2								
NT-ryegrass	8.26 a	7.90 b	7.15 a	6.28 b	5.93 a	5.46 b	5.52 a	4.93 a
CT-ryegrass	8.20 a	8.10 a	6.89 ab	6.86 a	5.91 a	6.22 a	5.08 ab	5.11 a
NT-bare	7.94 b	7.82 b	6.39 bc	6.02 c	5.11 b	5.01 c	4.52 b	4.31 b
CT-bare	7.94 b	7.79 b	6.28 c	5.98 c	4.96 b	5.17 bc	4.80 ab	4.72 ab
Week 5								
NT-ryegrass	8.25 a	7.87 a	7.02 a	6.41 a	5.70 a	5.37 a	4.09 a	3.57 a
CT-ryegrass	7.88 b	7.77 b	6.23 b	6.37 a	5.05 b	5.20 a	3.79 b	3.30 b
NT-bare	7.96 b	7.71 b	6.40 b	6.07 a	5.05 b	4.93 a	3.82 b	3.23 b
CT-bare	7.53 c	7.63 b	5.93 c	6.03 a	4.58 c	5.08 a	3.36 c	3.00 c
Week 8								
NT-ryegrass	7.98 a	7.80 a	5.94 a	6.20 a	2.35 a	5.14 a	4.29 a	4.22 ab
CT-ryegrass	7.73 b	7.66 a	5.99 a	6.22 a	1.59 ab	4.97 a	4.01 ab	4.37 a
NT-bare	7.62 bc	7.66 a	5.42 b	6.10a	1.67 ab	4.44 b	3.83 b	3.69 c
CT-bare	7.59 c	7.48 b	5.38 b	5.99 a	1.40 b	4.52 b	3.45 c	3.70 bc

INT = no tillage, CT = conventional tillage.

[2] Log (10) colony forming units per **g** soil **0.d.**

[3]**Means** within a column and sample period followed by the **same** letter **do** not differ at the 95% level.

Table 2. **Effect of rye and vetch cover crops on microbial populations and microbial biomass of a Dundee silt loam (0-2 cm), soybean study, 1994.**

Sample Time	Treatment'	Total Bacteria[2]	Gram Negative Bacteria*	Fluorescent Pseudomonads[2]	Total Fungi[2]	Microbial Biomass[3]
Planting	Bare	8.12 c[4]	6.59 b	5.04 c	3.22 a	76 b
	Rye	8.31 b	6.75 b	5.48 b	4.46 a	117 b
	Vetch	8.70 a	7.13 a	6.48 a	4.89 a	266 a
Week 3	Bare	7.51 b	5.93 a	4.53 b	3.48 a	81 b
	Rye	7.65 ab	6.13 a	4.64 b	3.94 a	121 a
	Vetch	8.03 a	6.45 a	5.42 a	4.16 a	114 a
Week 6	Bare	7.67 a	6.11 a	4.74 a	2.97 a	41 b
	Rye	7.47 a	5.89 a	4.00 a	2.72 a	74 a
	Vetch	7.26 b	5.94 a	4.53 a	3.44 a	59 ab
Week 11	Bare	1.56 a	6.35 a	4.98 a	3.47 a	91 c
	Rye	7.49 a	6.23 a	4.67 a	3.35 a	133 a
	Vetch	7.41 b	6.42 a	4.82 a	3.44 a	122 b

[1]BG = bareground, RC = rye cover crop soil, VC = vetch cover crop soil.
[2]log (10) colony forming units per g soil 0.d.
[3]μg ninhydrin reactive N released following chloroform fumigation per g soil 0.d.
[4]Means within a column and sample period followed by the same letter do not differ at the 95% level.

our Mississippi cotton study, although soils under NT had significantly greater organic carbon than those under CT. Major changes in microbial populations were associated with the ryegrass cover crop. Likewise, in the soybean study, both rye and vetch cover crops enhanced soil bacterial populations and microbial biomass.

Table 3. Bacterial populations of cover crop residues compared to underlying soils (at planting).

	Ryegrass'		Rye'		Vetch'	
Bacterial Group	Residue	Soil	Residue	Soil	Residue	Soil
Total	10.73	8.16	10.09	8.31	10.29	8.70
Gram Negative	9.42	6.68	9.12	6.75	8.86	7.73
Fl. Pseudomonads	8.22	6.27	7.95	5.48	7.59	6.48

'log (10) colony forming units per g material 0.d.

Table 4. Soil organic carbon content of the cotton and soybean studies at planting, 1994.

Treatment'	Organic Carbon (g/kg) 0-2 cm	2 - 10 cm
Cotton Study		
NT-Ryegrass	19.8 a[2]	5.1 a
NT-Bare	13.9 b	3.5 b
CT - Ryegrass	9.6 c	5.2 a
CT - Bare	8.0 c	4.5 ab
Soybean Study		
BG	13.6 a	9.9 a
RC	14.6 a	10.1 a
VC	15.3 a	9.4a

[1]NT = no-tillage, CT = conventional-tillage,BG = bareground, RC = rye cover crop soil, VC = vetch cover crop soil.
[2]Means within a column and cropping system followed by the same letter do not differ at the 95% level.

Results from both studies are similar to those of Kirchner et al. (1993) who demonstrated that a fall-seeded clover *(Trifolium incarnatum* L.) temporarily enhanced total bacterial and fungal populations. Our studies indicated that certain Gram-negative bacteria such as fluorescent pseudomonads are most affected by cover crops.

Herbicide-desiccated cover crops also enhanced soil enzyme activities in the surface soil (0-2 cm) in both studies. In the cotton study, soil in the NT-ryegrass treatment had greater esterase, phosphatase, and aryl acylamidase activity than soil in all other plots at all sample periods, while minimal effects of ryegrass were measured in CT soils (Table 5). In the absence of ryegrass, significantly greater enzyme activities were measured in NT than in CT plots at certain sampling times. Dick (1984) also found higher soil enzyme levels in NT soils than in CT soils. In the soybean study, both rye and vetch enhanced soil esterase, phosphatase, and aryl sulfatase activity compared to BG soils (Table 6). Soils from VC plots initially had significantly greater esterase and phosphatase activity than did soils from RC and BG plots; however, effects of the rye cover crop were more persistent.

Esterase activity is highly correlated with respiration and is a general indicator of microbial activity (Schunrer and Rosswall, 1982). Increased levels of phosphatase and aryl sulfatase, as well as other hydrolytic enzymes have been associated with soils previously cropped with clover (Kirchner et al., 1993). Phosphatase and sulfatase activity are indicators of potential nutrient availability since these enzymes release phosphate and sulfate, respectively, from organic pools. Enzymes such as esterase, aryl acylamidase, and aryl sulfatase may also be indicators of the potential for hydrolytic catabolism of several families of soil-applied herbicides.

Both studies demonstrated that herbicide-desiccated cover crops enhanced descriptors of biological soil quality, name-

Table 5. Effect of tillage and ryegrass cover crop on soil enzyme activities of a Dundee silt loam (0-2 cm), cotton study, 1994.

Tillage/ Cover Crop[1]	Esterase[2]	Aryl Acylamidase[3]	Alkaline Phosphatase[3]
Week 0			
NT-ryegrass	1096 a[4]	44.9 a	1219 a
CT-ryegrass	345 bc	9.9 b	565 b
NT-bare	507 b	15.3 b	896 b
CT-bare	233 c	9.9 b	565 b
Week 2			
NT-ryegrass	408 a	31.0 a	1187 a
CT-ryegrass	234 b	14.3 bc	864 b
NT-bare	220 bc	18.4 b	869 b
CT-bare	114 c	10.1 c	565 b
Week 5			
NT-ryegrass	526 a	26.1 a	1191 a
CT-ryegrass	221 bc	6.7 c	566 c
NT-bare	318 b	17.8 b	857 b
CT-bare	153 c	3.8 c	527 c
Week 8			
NT-ryegrass	201 a	3.1 a	nd
CT-ryegrass	122 bc	0.8 b	nd
NT-bare	141 b	0.5 b	nd
CT-bare	76 c	0.1 b	nd

[1]NT = no-tillage, CT = conventional-tillage.
[2]µmole/h/g soil o.d.
[3]nmoles/h/g soil o.d.
[4]Means within a column and sample period followed by the same letter do not differ at the 95% level.

Table 6. Effect of rye and vetch cover crops on soil enzyme activities of a Dundee silt loam (0-2 cm), soybean study, 1994.

Cover Crop[1]	Esterase[2]	Alkaline Phosphatase[3]	Aryl Sulfatase[3]
Week 0			
BG	88.1 c	494.8 c	143.8 b
RC	172.0 b	685.7 b	264.4 a
VC	242.4 a	859.8 a	263.6 a
Week 3			
BG	81.8 b	522.5 b	152.2 b
RC	154.4 a	634.7 a	266.8 a
VC	166.5 a	687.2 a	248.9 a
Week 6			
BG	78.2 b	470.5 ab	153.3 b
RC	139.6 a	564.4 a	260.2 a
VC	106.4 b	435.8 b	242.0 a
Week 11			
BG	97.1 b	504.4 ab	228.4 b
RC	139.8 a	641.5 a	311.7 a
VC	145.4 b	465.2 b	271.7 a

[1]BG = bareground, RC = rye cover crop soil, VC = vetch cover crop soil.
[2]µmole/h/g soil o.d.
[3]nmoles/h/g soil o.d.
[4]Means within a column and sample period followed by the same letter do not differ at the 95% level.

ly microbial biomass, microbial populations, and soil enzyme activities. These factors can potentially affect the availability of plant nutrients, organic matter transformations, and the fate of pesticides in the environment (Locke et al., 1995), all of which are important in the development of sustainable agricultural systems.

References

Dick, W.A. 1984. Influence of long-term tillage and crop rotation combinations on soil enzyme activities. Soil Sci. Soc. Amer. J. 48:569-574.

Doran, J.W. 1980. Microbial changes associated with residue management with reduced tillage. Soil Sci. Soc. Amer. J. 44:377-381.

Gould, W.D., C. Hagedorn, T.R. Bardinelli, and R.M. Zablotowicz. 1985. New selective media for enumeration and recovery of fluorescent pseudomonads from various habitats. Appl. Environ. Microbiol. 49:28-32.

Joergensen, R.G., and P.C. Brookes. 1990. Ninhydrin-reactive nitrogen measurements of microbial biomass in 0.5 M K_2SO_4 soil extracts. Soil Biol. Biochem. 22:1023-1027.

Kirchner, M.J., A.G. Wollum II, and L.D. King. 1993. soil microbial populations and activities in reduced chemical input agroecosystems. Soil Sci. Soc. Am. J. 57:1289-1295.

Liebl, R.W., W. Simmons, L.M. Max, and E.W. Stoller. 1992. Effect of rye mulch on weed control and soil moisture in soybean *(Glycine max)*. Weed Technol. 6:838-846.

Locke, M.A., R.M. Zablotowicz, and L.A. Gaston. 1995. Fluometuron herbicide interactions in crop residue-managed soils. In N.W. Buehring, and W.L. Kingery (eds.) Proc. Southern Conservation Tillage Conference for Sustainable Agriculture: Conservation Farming: A Focus on Water Quality. Jackson, MS.

Martin, J.P. 1950. Use of acid, rose bengal and streptomycin in the plate method for enumerating soil fungi. Soil Sci. 69:215-232.

Paul, E.A., and F.E. Clark. 1989. Soil microbiology and biochemistry. Academic Press, San Diego, CA.

Schunrer, J and T. Roswall. 1982. Fluorescein diacetate hydrolysis as a measure of total microbial activity in soil and litter. Appl. Environ. Microbiol. 43: 1256-1261

Tabatabai, M.A. 1982. Soil enzymes. p. 903 - 947. *In* A.L. Page, R.H. Miller, and D.R. Keeney, *(ed.)* Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. ASA-SSSA Agronomy Monograph no. 9, Madison, WI.

Zablotowicz, R.M. R.E. Hoagland, S.C. Wagner, and M.A. Locke. 1995. Aryl acylamidase activity in soil using 2-nitroacetanilide as substrate. Amer. Soc. Microbiol., 95th General Meeting, Washington, DC.

Low-Till Parabolic Subsoiler: A New Design for Reduced Soil Surface Disturbance and Power Requirement

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Introduction

Soil compaction has long been known to cause root restrictions and yield reductions in many crops, with cotton being particularly susceptible (Cooper et al., 1969). Two primary techniques were developed concerning the evaluation and management of soil compaction. The first method was subsoiling. Early research showed that the subsoiling produced significantly higher cotton yields than the conventional middle buster (Grissom et al., 1956). Lint yield increases with subsoiling have been reported, especially on sandy loam and silt loam soils, where subsoil compaction is a serious problem (Tupper, 1977).

The second method was to restrict wheel traffic in the same trafficked area between the rows each trip across the field, thus not allowing wheel traffic to occur over the growing zone (Williford, 1980). Raper (et al., 1994) reported no significant benefit to completely eliminating wheel traffic when in-row subsoiling occurred annually and traffic was restricted to row middles.

Subsoiling tools are designed to open up dense or impervious layers of soil for improved aeration, water infiltration, and root penetration. Research on the shape of subsoiler shanks was conducted at the National Tillage Machinery Laboratory in the 1950's (Nichols and Reaves, 1958). They found draft requirements with curved shaped shanks to be 7 to 20 percent less than with straight shanks. Draft was relatively insensitive to approach angles between 20" and 50" but increased very rapidly as the approach angle exceeded 50" (Payne and Tanner, 1959). Additional work further defined draft requirements and vertical forces on tillage tools with approach angles from 20 to 132º (Tanner, 1960).

The basic information developed by the research described above was incorporated into the Stoneviile parabolic subsoiler designed at the MAFES Delta Branch in 1972 (Tupper, 1974). Evaluations of the parabolic subsoiler revealed increased lint yields, lower horsepower requirements and reduced wheel slippage (43.4%) when compared to the straighter shank conventional subsoiler (Tupper, 1977). The parabolic subsoiler required 30.2% less fuel per acre than the conventional subsoiler, while working 2 inches deeper. Compared with the conventional and triplex subsoilers, the parabolic had the lowest draft, applied the highest vertical forces upon the soil, and had the lowest wheel slippage (Smith and Williford, 1988). Fewer than one percent of the Mississippi Delta cotton producers were subsoiling in 1975 (Cooke et al., 1975), but in 1992, more than 71% of Mississippi Delta cotton producers were subsoiling (Martin and Hamill, 1992).

New Federal legislation will require some changes in land preparation methods to meet requirements for reduced soil losses from fields. Residue cover on soil is recognized as a major factor affecting soil erosion (Meyer et al., 1970). Special subsoilers have been developed to reduce surface disturbance like the Paratill (The Tye Company or Bigham Brothers, Inc.) commonly referred to as "bent legged" or "L-shaped" shanks. These types of subsoilers are effective in reducing **soil** surface disturbance and maintaining ground cover but producers have noted high horsepower requirements.

The objective of this research was to meet the current needs of producers with interest in reduced tillage by designing a new parabolic subsoiler that would reduce soil surface disturbance and have lower draft requirements for in-row or across the row subsoiling.

Low-Till Parabolic Subsoiler Design

The low-till parabolic subsoiler was designed at the MAFES Delta Branch in the spring of 1993 (Tupper, 1994). The shank had a parabolic curve, with a long gradual increase in slope from an approach angle of 22.5" at the foot to 55" approach angle at the soil surface when running at the normal operating depth of 16 inches. The shanks were cut with an electric eye torch from 1%-inch T-1 steel plate with 321 Brinnel Hardness Number (BHN). Shanks were designed to provide a 17-inch ground clearance at operating depth or a total height of 33 inches.

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When soil is dry enough to shatter, rupture planes usually develop along a 45° plane up from the foot. Under less than ideal fracturing conditions, this angle tends to be less than 45° providing a narrower fractured zone. One of the design criteria used to reduce the power requirements was to keep the shank away from the fracture plane (less than 45° angle) *so* that it would always run in fractured soil. This design allowed only the subsoiler foot to run in hard unfractured soil. Another design criterion was to reposition the shank from following directly behind the foot, which minimizes the lifting of clods fractured by the foot to the soil surface like the original parabolic subsoiler. Reducing the lifting of clods through the topsoil layer would also reduce the power requirement and the amount of surface disturbance. Another design criterion was to sharpen the leading edge of the shank to reduce the lifting ability of the shank, also reducing the power requirement.

The low-till parabolic subsoiler was designed with the shanks positioned at a 28° angle from a vertical plane in the direction of travel. The top of each shank was directed away from the center of the tool bar. Placing the shanks at a 28" angle allows the shanks to always run inside the rupture planes developed by the foot, even when soil conditions are less than ideal for good fracture. Each shank was positioned on the tool bar *so* that the foot (row spacing width) can run directly under the drill row. The angle of the shank moves the top of the shank away from being directly over the drill. The shank's position prevents the leading edge from lifting large clods to the surface. Also, it provides more clearance for trash to minimize plugging under minimum till/high debris conditions. This design allows a producer to subsoil in the row direction prior to shredding cotton stalks, whereas, the conventional parabolic subsoiler plugs with stalks. A 45 ° angle was cut on the upper side of the leading edge of the shank to provide a sharp leading edge. This sharp leading edge reduces the lifting ability of the shank thus reducing soil lift or surface disturbance and the power requirements of the shank. The reduced surface disturbance helps maintain ground cover for erosion control.

The subsoiler foot is 3 inches wide and has a 22.5" approach angle for minimum draft (Tanner, 1960), and a minimum of 360 BHN on the upper and lower surfaces for wear resistance. The foot runs in a position similar to the original parabolic subsoiler foot. This position is obtained by cutting an opposite 28° angle to the lean of the shank in a horizontal plane on the upper and lower edge of the point of the shank where the foot attaches to the shank. Side plates on the foot are leaned at a 28" angle parallel to the shank and a roll-pin is used to attach the foot to the shank.

A four-shank low-till parabolic subsoiler was constructed at Stoneville using a 5 x 7 **x** 1/2-inch tool bar. A category III three-point hitch was mounted on a shorter second 5 **X** 7 x 1/2-inch tool bar, which was mounted 17 inches ahead of the long tool bar on which the shanks are mounted. Two gage wheels were attached to the long tool bar and mounted to run behind the subsoiler in the row middles.

Field Tests

Field tests began in the fall of 1993. The studies were arranged in split plot experiments with two main plots: (1) check and (2) conventional parabolic subsoiler at a 45° angle to the row in the fall. The subplots consisted of five treatments: (I) check; (2) paratill in-row, fall; (3) paratill in-row, spring; (4) low-till parabolic in-row, fall; and (5) low-till in-row, spring. Each of the five treatments had (1) check or (2) alternate middle chisel operated 12 inches deep in nontraffic middles after emergence. The studies were 2 x *5* x 2 factorial experiments for 20 total treatments with six replications on two soil types: Bosket very sandy loam soil and Forestdale silty clay loam soil. The research was supported in part by the Mississippi Cotton Incorporated State Support Program (MCISSP) and by Cotton Incorporated.

First-year preliminary results showed the conventional parabolic subsoiler, operated at 45" to the row direction in the fall, was best on the Bosket very fine sandy loam soil type. Fall in-row subsoiling tended to produce higher yields than spring in-row subsoiling on the sandy soil type and the alternate middle chisel did not increase lint yield. On the Forestdale silty clay loam soil spring in-row subsoiling produce higher yields than fall-in row subsoiling.

A field performance test was run on Forestdale silty clay loam soil with the two in-row subsoilers set to run 16 inches deep. A 195-PTO Hp Case IH® 7240 tractor was used to pull the subsoilers. The criteria used in the study were to run the tractor at full throttle and maintain 2,100 to 2,200 engine RPM by shifting down or up a gear, respectively, to vary draft load to maintain engine RPM within this range. Alternate four-row plots were subsoiled with each subsoiler across a field with rows 480 feet long. The 7240 was able to pull the Paratill at a field performance rate of 8.16 A/hour and the low-till parabolic subsoiler at a rate of 9.09 A/hour, for an 11.4% increase in performance rate. Both in-row subsoilers were run without busters. Additional research will be conducted and reported as data are available.

Note: The use of trade names in this publication is solely to provide specific information and does not imply their approval or recommendation by the Mississippi Agricultural and Forestry Experiment Station to the exclusion of other products.

Literature Cited

1. Cooke, F. T., Jr., J. M. Anderson, D. W. Parvin, Jr., A. M. Heagler, K. W. Paxton, S. H. Holder, Jr., and J. G. Hamill. 1975. Crop budgets and planning data for major farm enterprises in the Mississippi, Louisiana Delta, 1975. Miss. Agric. and Forestry Exp. Sta. Bull. 834. 79 p.
2. Cooper, A. W., A. C. Trouse, and W. T. Dumas. 1969. Controlled traffic in row crop production. *In* Proc. of the 7th Int. Congress of Agric. Eng. 106, Baden-Baden West Germany, Theme 1.
3. Grissom, P. H., E. B. Williamson, O. B. Wooten, F. E. Fulgham, and W. A. Ranney. 1956. Subsoiling results at the Delta Station in 1955. Information Sheet 535. Mississippi Agric. Exp. Station.

4. Martin, R. J., and J. G. Hamill. 1992. Cotton 1993 planning budgets. Agri. Eco. Rpt. 51, MAFES and MCES, 88 p.

5. Meyer, L. D., W. H. Wischmeier and G. R. Foster. 1970. Mulch rates required for erosion control on steep slopes. Soil Sci. Soc. Am. Proc 34(6):928-931.

6. Nichols, M. L., and C. A. Reaves. 1958. Soil reaction to subsoiling equipment. Agricultural Engineering 39(6):340-343.

7. Payne, P. C., Jr. and D. W. Tanner. 1959. The relationships between rake angle and the performance of simple cultivation implements. Jour. Agr. Eng. Res. 4:312-325.

8. Raper, R. L., D. W. Reeves, E. C. Burt, and H. A. Turbert. 1994. Conservation tillage and traffic effects on soil conditions. Trans. of ASAE Vol. 37(3):763-768.

9. Smith, L. A., and J. R. Williford. 1988. Power Requirements of conventional, triplex, and parabolic subsoilers. Trans. of ASAE. 31(6):1685-1688.

10. Tanner, D. W. 1960. Further work on the relationship between rake angle and the performance of simple cultivation implements. Jour. Agr. Eng. Res. 5:307-315.

11. Tupper, G. R. 1974. Design of the Stoneville parabolic subsoiler. Information Sheet 1249. Miss. Agri. and Forestry Exp. Sta., Miss. State, Mississippi 3p

12. Tupper, G. R. 1977. Evaluation of the Stoneville parabolic subsoiler. Bulletin 858. Miss. Agri. and Forestry Exp. Sta., Miss. State, Mississippi, 7p.

13, Tupper, G. R. 1994. Design of the low-till parabolic subsoiler. Proc. Beltwide Cotton Conferences. p. 531.

14. Williford, J. R. 1980. A controlled-traffk system for cotton production. Trans. of ASAE 23(1):65-70.

Long-Term Crop Response to Conservation Tillage

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Introduction

In 1987, the United States Department of Agriculture (USDA-ARS) National Sedimentation Laboratory, in cooperation with the Mississippi Agricultural and Forestry Experiment Station (MAFES) and the Natural Resources Conservation Service (NRCS), initiated an interdisciplinary research project to develop profitable and environmentally sustainable conservation production systems for silty upland areas of the Midsouth.

Results from the first 5 years of this project were reported to the SCTC in 1993. Culture details and soil types are listed in the earlier paper (Dabney et al., 1993). Treatments included no-tillage, conventional (chisel, disk, cultivate), ridge, and minimum tillage for cotton, grain sorghum, and soybeans. A wheat-soybean and grain sorghum-wheat-soybean doublecrop (three crops in 2 years) systems were also included. No-tillage cotton followed wheat cover and no-tillage sorghum followed vetch cover. In this phase, both no-tillage cotton and grain sorghum yields improved with time relative to conventional tillage, while crop yields with minimum and ridge-tillage were similar to those with conventional tillage.

We reported earlier that soil loss from runoff plots with no-tillage was in the range of 1 to 2 tons/acre/year, sufficient for conservation compliance. An economic analysis of cropping systems showed the doublecrop wheat-soybean system to be the most profitable, no-tillage cotton was profitable, and all continuous grain sorghum systems were unprofitable (Dabney et al., 1993).

After the fifth crop year, the study was revised. No-tillage replaced minimum and ridge tillage, corn replaced grain sorghum, and full-season no-tillage soybeans and a corn-cotton rotation were initiated (Table 1). The first-phase conventional and no-tillage were retained. New no-tillage corn and cotton were with and without cover crops. The new design permits evaluation of the: (1) time in no-tillage (tillage history), (2) cover crops within no-tillage systems, and (3) crop rotation.

Objectives of this revised study were: (1) to monitor long-term crop responses to conventional and no-tillage, (2) to evaluate crop responses when changing to an untilled environment, and (3) determine the effect of crop rotation on crop productivity in untilled systems. Results from the first 2 years of the revised study are reported here.

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Methods

Treatments were evaluated in 40- by 18-foot plots in a randomized block design with 10 replications. All crops were planted in 36-inch rows except wheat and soybeans, which were drilled in 7-inch rows. Full-season soybeans were planted in May and doublecrop soybeans were planted in early June. Conventional cotton and corn were chisel-plowed and disked in spring, cotton planted on low ridges, a band herbicide application made, and both crops cultivated. Herbicides for no-tillage included preemergence applications of contact and residual materials and postemergence or post-directed applications as needed to maintain weed control. Uncontrolled weeds have not been a factor in crop productivity for this study.

Rates of P and K were based on soil test and were applied broadcast before tillage. Nitrogen rates for corn, wheat, and cotton were in the mid to high range.

The study was located on loess soils in north Mississippi near Senatobia. Soils included Grenada silt loam, (fine silty, mixed, thermic Glossic Fragiudalf), Loring (fine silty mixed thermic Typic Fragiudalf), and Memphis (fine silty mixed thermic Typic Hapludalf). Other details for first-phase methods were published earlier (Dabney et al., 1993).

Table 1. Tillage and cropping treatments for phase two of the tillage and rotation study.

Tillaee and crop	Date tillage system initiated
CTCO Conventional cotton	1988
NTCO-W-1 No-till cotton, wheat cover	1988
NTCO-W-2 No-till cotton, wheat cover	1993
NTCO No-till cotton, volunteer cover	1993
NTCO/CR No-till cotton corn rotation	1993
CTSB Conventional soybean	1988
NTSB No-till soybean, full season	1993
NTSB/W No-till wheat soybean doublecrop	1988
NTSB/W-CR No-till soybean/corn/wheat doublecrop	1988
CTCR Conventional corn	1988
NTCR-V No-till corn, vetch cover	1988
NTCR No-till corn, volunteer cover	1993
NTCR/SB No-till corn/wheat/soybean	1988
NTCR/CO No-till corn/cotton rotation	1993

CT: conventional tillage. NT: no-tillage.

Results

Weather

In 1993, early growing season rainfall was adequate to support excellent corn production but drought later limited both soybean and cotton yields. In 1994, rainfall was adequate and well distributed. Monthly rainfall totals are shown in Table 2 for the two growing seasons.

Cotton Yields

Long-term no-tillage cotton following wheat cover yielded 53% greater than long-term conventional tillage in 1993 (Table 3). Yields of first-year no-tillage treatments equalled conventional, regardless of cover crop or rotation. Thus, during this season with limited moisture first-year no-tillage did not equal the longer term no-tillage. During 1994, long-term no-tillage cotton yielded 29% greater than long-term conventional tillage. Yields of all second-year no-tillage treatments were greater than conventional.

Soybean Yields

In 1993, all soybean treatment yields were equal (Table 4). In 1994, full-season no-tillage soybean yields were 31% greater than conventional while both doublecrop systems were lower than full-season no-tillage but not different from the conventional. Conventional and doublecrop systems were not significantly different.

Corn Yields

In 1993, long-term no-tillage corn in the corn/wheat/soybean rotation yielded 34% greater than conventional tillage while all other treatments were equal to conventional tilled or greater. During 1994, with ample moisture, conventional corn yields equalled all other treatments and were greater than no-tillage corn following vetch cover. No-tillage corn following vetch suffered a stand loss and was replanted in May with the later planting likely reducing yield potential (Table 5). Yields of better treatments were in the 120-to 130-bushel range during both years, a profitable level based on our economic analysis.

Wheat Yields

During 1993, wheat yields averaged 39 bu/A and in 1994 wheat in the doublecrop system (two crops each year) averaged 38 bu/A. Wheat following corn yielded 51 bu/A, significantly greater than the continuous doublecrop system.

Discussion

This research is identifying crop management systems for highly erodible soils that both sustain crop productivity and reduce soil loss to an acceptable level. The positive yield response of cotton to no-tillage that we report differs from reports by Brown et al. (1985), and Stevens et al. (1992). These studies, and a study by Burmeister et al. (1993) in which conventional tillage was equal to or better than no-tillage, occupied sites previously tilled for annual cropping for several years. Neither the Brown nor Stevens studies were continued for more than 3 years. In both phases of our study, first-year no-tillage cotton yields were either equal to or less than conventional yields and at least 2 years of no-tillage were required for yield differences to become strongly evident.

Lack of immediate response to no-tillage implies that phys-

Table 2. Growing season rainfall at the study site, inches/month.

Year	May	June	July	Aug	Sep
1993	3.08	3.94	0.27	5.01	6.53
1994	3.12	6.44	5.43	5.84	0.37

Table 3. Yield of DES 119 cotton as influenced by tillage and rotation, 1993 and 1994.

System	Tillage duration 1994	Seed cotton yield 1993	Seed cotton yield 1994
	(years)	(lb/acre)	(lb/acre)
CTCO	7	770 bc	1,700 b
NTCO-W1	7	1,180 a	2,190 a
NTCO-W2	2	920 bc	1,960 a
NTCO	2	830 bc	2,000 a
NTCO/CR	2	980 b	2,130 a

Within columns, means followed by the same letter do not differ at the 0.05 significance level using Duncan's multiple range test.

Table 4. Soybean yields as influenced by tillage and rotation, 1993 and 1994.

System	Tillage duration 1994	Soybean yield 1993	Soybean yield 1994
	(Years)	(Bu/acre	(Bu/acre)
CTSB	7	20 a	29 b
NTSB	2	25 a	38 a
NTSB/W	7	22 a	25 b
NTSB/W-CR	7	22 a	21 b

Within columns, means followed by the same letter do not differ at the 0.05 significance level using Duncan's multiple range test.

Table 5. Corn yields as influenced by tillage and rotation, 1993 and 1994.

S-ystem	Tillage duration 1994	Corn yield 1993	*Corn* yield 1994
	(Years)	Bu/acre)	(Bu/acre)
CTCR	7	95 c	133 a
NTCR-V	7	110 abc	106 b
NTCR	2	97 bc	123 ab
NTCR/SB	7	127 a	130 a
NTCR/CO	2	117 ab	130 a

Within columns, means followed by the same letter do not differ at the 0.05 significance level using Duncan's multiple range test.

ical, chemical, or biological soil conditions must evolve in some way before the full potential of the system is manifest. Langdale, working on an ultisol in Georgia, reports a requirement of several years before no-tillage cotton yields exceeded those of conventional tillage (G. W. Langdale, personal communication). The relative response of tillage systems to growing season rainfall indicates moisture availability is a likely component in tillage response. Similar results with corn were reported in a long-term study on a soil similar to ours (Dick et al., 1991).

In the first phase of this study, no-tillage grain sorghum-soybean rotation yielded more than continuous grain sorghum. Increased grassy weeds in wheat in continuous wheat-soybean doublecrop increased herbicide costs and reduced yields. Second-phase crop rotations have been a component of this study for only two seasons, too little time to fully assess the value of this practice. Wheat and corn had significant rotation effects for one year. Aside from crop yield response, there are several valid reasons for rotating crops. Problem weeds in corn can be controlled with herbicides available for soybeans or cotton, and the reverse is also true. Corn or grain sorghum provide more residue than cotton or soybeans, an important factor in conservation compliance on sloping sites,

Our results indicate that on this well-drained highly erodible soil, crop yields are being maintained with no-tillage cropping in systems that comply with soil loss restrictions. This study will be continued for several years to fully assess long-term yield trends.

Varied crop yield results from full-season no-tillage have been reported by several participants at the Southern Conservation Tillage Conference. We suggest that these results be considered collectively and an effort made to identify situations where no-tillage systems succeed or fail, and why. Certainly, with the highly erosive rainfall in the Midsouth, we need systems that will protect our soil resource. As a given, any system must have adequate stands and weed control. If either of these fail, we need look no further to explain yield differences. Where stands and weed control are adequate, other reasons for differences include the following:

1. Soil type x tillage interactions

Possibly, some soils should be tilled for optimum crop productivity while others may be better left undisturbed. If such situations are identified, this does not mean that some form of reduced tillage is not possible, and no-tillage may be desirable for reasons other than yield. Systems that maintain yields while protecting our soil resource need to be developed. In some Midwest studies, poorly drained soils are seemingly less suited to no-tillage than better drained soils (Dick et al., 1991). In poorly drained soils, a mollic epipedon seems to further reduce positive crop responses to no-tillage (Griffith et al., 1988). Triplett and Van Doren (1985) reported that plowing in alternate years maintained corn yields on a poorly drained mollic soil (rotating tillage). In the lower coastal plains, in-row subsoiling seems necessary for successful no-tillage.

2. Cropping sequence

Rotating crops may have a positive effect on no-tillage yields. Dick et al. (1991) reported reduced yields for continuous no-tillage corn on a poorly drained soil. If corn was rotated with soybean, yields were maintained equal to fall plowing. Crop rotation permits selection of herbicides that aid in control of weeds that are problems in monoculture.

3. Nitrogen fertility

Tillage increases the rate of organic matter oxidation and release of nitrogen. Thus, nitrogen rates for no-tillage may need increasing to realize the full potential of the system. Fox and Bandel (1986) reported lower corn yields for no-tillage at low rates of nitrogen and higher yields at increased nitrogen rates. Eventually, an equilibrium should be reached with the two systems as the organic matter content of the no-tillage system increases.

4. Mulch cover

Mulch serves to reduce soil erosion and increase water infiltration but can interfere with planting and harbor disease and insect pests. Water management, increased infiltration during the growing season, may be a major contribution of mulch on some soils. Conversely, mulch may be less important on vertisols that crack when dry. Winter weed growth in the Midsouth provides cover before crop planting. However, allowing vegetative growth late in the planting season can deplete soil moisture and reduce crop productivity. Thus, time of weed kill is an important factor in crop management in no-tillage systems.

5. Length of time in no-tillage

As agronomists, we commonly conduct field studies for three seasons to reasonably sample years. In this study, no-tillage was initiated twice and, in one case, the first-year results were less than conventional, and equal in the other. Crops grown with no-tillage improved with time. Dick et al. (1991) reported long-term improvement of no-tillage relative to conventional, even on poorly drained soils. Langdale et al. (1992) also needed several years for full response to no-tillage to develop. Thus, short-term studies may be inadequate to assess the full effect of the system. Continuous no-tillage reduces soil loss and contributes to other changes in the soil environment. At present, there is inadequate evidence to determine cause and effect relationships for yield trends.

6. Cropping history

Tilled cropping degrades soil physically and chemically. No-tillage initiated on a site cropped for several years may not respond the same as when following sod. The study reported here was in sod for a short time before the research was initiated. Perhaps soil conditions, including tillage history, should not be overlooked when evaluating response to no-tillage.

7. Soil biology

Invertebrates such as earthworms, which serve to form stable macropores, are reduced under tilled systems. There may be a period of time required before these and other organisms are fully functional when converting to no-tillage, especially when following tilled cropping. Mycorrhiza are receiving increasing attention as a possible factor in no-tillage crop response. These and other systems must be considered.

We do not consider this list is necessarily complete, but hope that it will serve to initiate dialogue among members of this group.

Literature Cited

Brown, S. M., T. Whitewell, J. T. Touchton, and C. H. Burmeister. 1985. Conservation tillage systems for cotton production. Soil Sci. Soc. Am. J. 49:1256-1260.

Burmeister, C. H., M. G. Patterson, and D. W. Reeves. 1993. No-till cotton growth characteristics and yield in Alabama. In P. K. Bollick (ed). Proceedings of the 1993 Southern Conservation Tillage Conference for Sustainable Agriculture. pp 30-36

Dabney, S. M., C. E. Murphree, G. B. Triplett, E. H. Grissinger, L. D. Meyer, L. R. Reinschmiedt, and F. E. Rhoton. 1993. Conservation production systems for silty uplands. In Bollick, Patrick K. *(ed.)* Proceedings of the 1993 Southern Conservation Tillage Conference for Sustainable Agriculture. Monroe LA. pp 43-48.

Dick, W. A,, E. L. McCoy, W. M. Edwards, and R. Lal. 1991. Continuous application of no-tillage to Ohio soils. Agron. J. 83:65-73.

Fox, R. H,. and V. A. Bandel. 1986. Nitrogen utilization with no-tillage. In M. A. Sprague and G. B. Triplett (eds). No-Tillage and Surface Tillage Agriculture. John Wiley and Sons. New York.

Griffth, D. R., E. J. Kladivko, J.V. Mannering, T. D. West, and S. D. Parsons. 1988. Long-Term tillage and rotative effects on corn growth and yield on high and low organic matter poorly drained soils. Agron. J. 80:599-605.

Langdale, G. W., L. T. West, R. R. Bruce, W. P. Miller, and A. W. Thomas. 1992. Restoration of eroded soil with conservation tillage. Soil Tech.(5) 81 90.

Stevens, W. E., J. R. Johnson, J. J. Varco, and J. Parkman. 1992. Tillage and winter cover management effects on fruiting and yield of cotton. J. Prod. Agric. 5:570.575.

Triplett, G. B. Jr., and D. M. Van Doren Jr. 1985. An overview of Ohio conservation tillage. *In* M. D'Itri *(ed)* A Systems Approach to Conservation Tillage. Lewis Publishers, Inc., Chelsea, MI.

Post-CRP Land Management and Sustainable Production Alternatives for Highly Erodible Lands

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Introduction

Oklahoma has 1.2 million acres enrolled in the Conservation Reserve Program (CRP). Eighty-eight percent of the acreage is in the Panhandle and in counties along the Texas-Oklahoma border. Prior to the CRP, much of this land was cropped annually to winter wheat. Dryland cotton production in southwestern Oklahoma and dryland sorghum production in northwestern Oklahoma were also important. Wind erosion, water erosion, and associated particulate nutrient discharge were significant production problems with these crops. Removing these soils from crop production and establishing perennial grass cover has significantly reduced soil erosion.

Old World bluestem (OWB), a perennial bunchgrass, was used extensively for soil cover on many of the contract acres because of an abundant, relatively inexpensive seed supply and ease of establishment. Unfortunately, most producers do not fully understand the forage potential of the grass and will be unaware of how to manage the grass after the CRP.

Literature

Government contracts to retire highly erodible land for 10 years were established in Title XI1 of the Food Security Act of 1985. However, soon after the program's inception, the very nature of its merit; the program's implementation strategies, benefits and deficiencies; and its future use have been extensively debated (Cacek, 1988; Dicks and Coombs, 1993; Dicks, 1994; Mitchell, 1987; Osborn, 1993; Ribaudo, et al., 1989).

As Congress begins addressing the 1995 Farm Bill, the future of these acres is still uncertain. Most certainly this program will see changes and the acreage will not likely be expanded. Some fear a total elimination of the program may occur, and with it, the benefits of a long-term CRP. Although the political and societal attitudes toward sustainable use of land resources and market forces are difficult to predict, impediments to sound use of fragile, environmentally-sensitive lands must be addressed before the expiration date of contracts.

A number of state projects have been implemented, primarily to evaluate the potential use of CRP lands in forage-livestock and/or seed production enterprises (Prinz, 1993). Although that approach appears to be the most consistent for future use, there is increasing evidence that many producers will revert to annual crop production systems.

A recent survey conducted by the Soil and Water Conservation Society (Nowak, Schnepf, and Barnes, 1991) suggests that as many as 46 percent of respondents have plans for using their CRP land after the contracts expire and will return one-half to crop production.

Conservation tillage, including no-till cropping systems, is seen as a way of preserving many of the benefits of CRP, and, at the same time, allowing commodity crop production on highly erodible land. A large information base has been developed on conservation tillage over the past decades (Dao and Nguyen, 1989; Stiegler, 1987; Unger and McCalla, 1980.)

It is apparent that many soil processes require several years to establish a new equilibrium when tillage is reduced or eliminated. Tillage operations significantly alter the ecological balance both above and below ground. Tillage operations mix soil, therefore increasing microbial oxidation of soil organic matter and the degradation of soil structure. While a great deal will depend on economics and the market condition in 1996 and 1997, it is apparent that some of the land will return to crop production.

Research and Demonstration

In 1994, a multi-agency (USDA-ARS, Oklahoma State University, Noble Research Foundation, UDSA-NRCS and USDA-CFSA, Oklahoma Conservation Districts, and others) project was initiated with funding provided by the Southern Region SARE/ACE program. This is a 3-year project. The objectives of this farm-scale, research and demonstration study are designed to answer the following questions.

(1) What are the best management practices for the existing grass cover to maximize grass production and potential beef weight gains?

(2) What soil quality improvements in the soil resource base have been made during the CRP, and what is the relative persistence of the improvements under alternate land management practices after CRP?

(3) How and when is the best time to kill existing grass cover if a commodity crop is to be successfully produced in the transition year out of CRP?

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(4) What are the best management options and guidelines for enironmentally-sound, sustainable, alternative cropping systems?

Research Approaches and Methods

Project Area

The research and demonstration study is being conducted at two sites. One is located in a semi-arid region on a wind-erosion-prone Dalhart fine sandy loam (Aridic Haplustalf) soil in northwestern Oklahoma near Forgan. The average rainfall is 18 inches annually. The other site is located in a subhumid region on a water-erosion-prone La Casa clay loam (Pachic Paleustoll) soil in southwestern Oklahoma near Duke. The average rainfall is 26 inches annually.

The sites are located on producer farms, on land that has been in CRP grass for 7 to 8 years. Enough land was acquired so that a completely new study area will be used at each site in each of the 3 years of the project as well as following the initial plots through a 3-year cycle.

Producer involvement in the project was stressed by SARE/ACE; however, because CRP guidelines forbid haying, tilling, or otherwise destroying the sod on contract acres, permission from Consolidated Farm Services Agency (CFSA) was requested and received for the use of the land. Landowners continue to receive annual rental payments. The only CFSA restriction is that the landowner cannot benefit for the sale of any hay or crop from the acres; however they can receive payments for services provided to the investigators.

Research Approach and Treatment

At the northwestern site, eight one-acre replicated treatments are being evaluated. They are **(1)** OWB hay production from unimproved plots; **(2)** OWB hay production from managed and fertilized plots; **(3)** minimum-tilled and annually planted winter wheat production for forage; **(4)** minimum-tilled and annually planted winter wheat for forage and grain; **(5)** no-till and annually planted winter wheat in killed sod for forage; **(6)** no-till and annually planted winter wheat for forage and grain; **(7)** no-till wheat-fallow-sorghum rotation; and **(8)** conventionally tilled annually planted sorghum.

The OWB biomass was burned in the spring of 1994 before the plots were installed. No-till plots were sprayed with glyphosate at 1 lb ai/acre + ammonium sulfate. Minimum tillage was performed using an offset disk (small plots) or a large V-blade (large plots).

At the southwestern site, the plot sizes are different but the first six treatments are the same as the northwestern site. Two other treatments, conventionally tilled and row or strip-tilled cotton, will be planted into a killed winter wheat cover crop. The OWB biomass was mowed and hayed in the spring before the plots were installed. No-till plots were sprayed with glyphosate at 1 lb ai/acre + ammonium sulfate two times during the OWB growing season. The minimum tillage was performed using an offset disk twice prior to wheat seeding.

Accumulated benefits of CRP lands such as enhanced organic matter content, hydraulic properties, and other pertinent physical characteristics such as aggregate stability will be monitored. Their changes under the various management options will be determined to illustrate the relative persistence of accrued benefits to the soil resource. It is intended that the project will illustrate the relative costs of production for the various management options. The economic returns from cropping highly erodible lands will be compared with the returns from maintaining the grass cover for grazing livestock.

In addition to the large plots, four small-plot studies are being conducted at each location. These small plots are designed to study an array of tillage methods, mowing, and herbicide options for killing the OWB grass. Studies to determine the influence of fertilizer on residue decomposition, weed populations, and crop yields are being conducted. Also, the effects of fall- and spring-applied weed control options in the crops being grown and their effect on crop production are being studied.

Educational activities will be organized for local producers. Field days, workshops, and tours of research and demonstration areas will be conducted for end-users' first-hand evaluation. In addition, progress reports, technical articles, and popular literature will be prepared to summarize achievements and provide management guidelines.

Results and Discussion

Considerable data are being collected and the plots are being monitored on a regular basis, but none of the data are ready for release at this time. The project was just initiated in the spring of 1994. A few items can be discussed.

Killing of OWB, regardless of pretreatment (burning or mowing) proved more difficult with glyphosate because of the climate and moisture stress conditions. Moldboard plowing was an effective means for killing the OWB sod. Disking gave somewhat reduced kill. The large V-blade plow provided a good kill on the large plots at the northwestern site but could not be used on the fine-textured soils at the southwestern site.

Wheat stands at both sites were rated as adequate in all treatments, partially due to timely rains after planting. Moldboard and disk plots (planted with conventional drill) had somewhat better stands than the no-till plots (planted with a no-till drill).

References

Cacek, T., 1988. After the CRP contract expires. J. Soil Water Conserv. 43:291-293.

Dao, T.H., and H.T. Nguyen. 1989. Growth response to cultivars to conservation tillage in continuous wheat cropping system. Agron. J. 81:923-929.

Dicks, M.R., and J.E. Coombs. 1993. CRP in the future. Great Plains Agricultural Policy Center, Okla. Agri. Exp. Sta. Res. Report 938.

Dicks, M.R. 1994. *Ed.* Post conservation reserve program land use. Proceedings of the NCT -163 Conference. Jan. 10-11, 1994. Denver, CO.

Mitchell, M.E. 1987. **Ed.** Impacts of the Conservation Reserve Program in the Great Plains. Proceedings. Sept. 16-18, 1987. Ft. Collins, CO. USDA Forest Service, Gen. Tech. Rep. RM-158.

Nowak, P.J., M. Schnepf, and R. Barnes. 1991. When conservation reserve program contracts expire. A national survey of farm owners and operators who have enrolled land in the Conservation Reserve. Soil and Water Conservation Society, Ankeny. IA.

Printz, J.L., 1993. North Dakota's CRP grazing and haying demonstration project. Rangelands 15:163-165.

Osborn, T. 1993. The Conservation Reserve Program: Status, future, and policy options. J. Soil Water Conserv. 48:271-278.

Ribaudo, M., S. Piper, G. Schaible, L. Langer, and D. Colacicco. 1989. CRP, what economic benefit? J. Soil Water Conserv. 44:421-424.

Stiegler, **J.H.** 1987. Conservation tillage adoption: A survey of research and educational needs. Conserv. Tech. Info Center, W. Lafayette, IN.

Unger, P.W. and T.M. McCalla. 1980. Conservation tillage systems. Adv. Agrono. 33:1-58.

Cotton Response to Reduced Tillage and Cover Crops in the Southeastern Coastal Plain

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Abstract

Understanding how cotton *(Gossypium hirsutum* L.) responds to alternative production practices will improve management of the crop in those systems. Our objective was to determine the influence of a rye cover crop and reduced tillage on soil strength, cotton development, and lint yield. Treatments consisted of winter cover [rye *(Secale cereale* L.) and fallow], surface tillage (disking and none), and deep tillage (in-row subsoiling and none). Differences in soil strength occurred between treatment combinations, but because of sufficient precipitation during the growing season, deep tillage did not impact any other variable. Following winter fallow, there were no differences in the initiation of reproductive growth or crop yield between disking and no surface tillage. The presence of a rye surface mulch, however, delayed flower initiation. Cotton lint yield was not influenced by surface tillage following winter fallow. Following rye, cotton yield and plant populations were lower when the residues were left on the surface. Although further verification is needed, production aids such as crop growth simulation models may require modification for application in situations where cotton is grown in fields with large amounts of surface residues.

Introduction

Surface residues are an important component of conservation tillage crop production systems in the southeastern United States of America. Langdale et al. (1990) concluded that a cropping system that included both cool- and warm-season annual crops was needed for successful production of sorghum *[Sorghum bicolor* (L.) Moench] and soybean *[Glycine max* (L.) Merrill] with conservation tillage on Piedmont sandy loam soils. In continuous monocropped cotton, residues after harvest are low and, because of the long growing season needed by the crop, doublecropping with a winter small grain cash crop is not possible for much of the region. Winter annual cover crops, seeded in the fall and terminated before planting in the spring, can provide adequate surface residues for conservation tillage production of cotton.

Beyond erosion control, a primary benefit of surface residues in conservation tillage is improved soil water status. In-row subsoiling on coastal plain soils is done to disrupt a root-restricting E horizon that limits root growth into the clay-textured B horizon. If combined with controlled traffic, residues from cover crops may alleviate the need for annual deep tillage on these soils, as prescribed by Busscher et al. (1986a).

Changes in soil conditions with use of reduced tillage and cover crops influence crop development. Compared to conventional tillage cotton, conservation tillage cotton differs in boll size and distribution within the canopy (Hoskinson and Howard, 1992). Stevens et al. (1992) found that cotton seeded into wheat cover crop stubble had fewer flower buds on mainstem nodes five through eight than conventional tillage cotton. For optimal cotton crop management, an understanding of plant development is needed. Our objective was to determine the influence of a rye cover crop and reduced tillage on soil strength, cotton development, and lint yield.

Materials and Methods

We conducted this experiment in 1994 at the Clemson University Pee Dee Research and Education Center near Florence, SC. Cover crop and surface tillage plots were established in the fall of 1990. Results from experiments in 1991 and 1992 have been reported previously (Bauer and Busscher, 1993). Cotton was grown on the plots in 1993, but plots were not harvested because of drought. All plots were in-row subsoiled in 1993. Treatments in 1994 consisted of winter cover (rye and fallow), surface tillage (disking and none), and deep tillage (in-row subsoiling and none). The soil was a Norfolk sandy loam (fine, loamy, siliceous, thermic, Typic Kandiudult).

The experimental design was randomized complete block with treatments in split-split plot arrangement. Main plots were winter cover, subplots were surface tillage, and sub-subplots were deep tillage. The experiment had four replicates. Sub-subplot sue was 12.7 feet wide (four 38-inch rows) by 50 feet long.

After the cotton stalks were shredded in the fall of 1993, rye (110 pounds of seed acre) was seeded with a John Deere

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750 grain drill on October 19 in rows spaced 7.5 inches apart.

Winter cover above-ground biomass was determined on April 25 by drying a 11.5-ft² sample from each surface tillage subplot in the fallow main plots and a 6.4-ft² sample from each surface tillage subplot in the rye main plots. On May 3, the appropriate plots were either disked or dessiccated with paraquat. The deep tillage plots were subsoiled within 6 inches of the 1993 rows with a KMC four-row subsoiler prior to planting in an operation separate from seeding. Cotton ('DES 119') was seeded within 6 inches of the 1993 rows on May 18 with a four-row Case-IH 900 series planter equipped with Yetter wavy coulters.

Nitrogen (80 lb N/acre as ammonium nitrate) was applied in a split application, with half applied at planting and the other half applied a month after planting. The N was banded approximately 4 inches deep and 6 inches from the cotton rows at each application time. Lime, P, K, S, B, and Mn were applied based on soil test results and Clemson University Extension recommendations. Weed control was accomplished with a combination of herbicides, cultivation (disked plots only), and hand-weeding. Aldicarb (0.75 lb ai/A) was applied infurrow and other insecticides were applied as insect pest infestations warranted.

Soil strength was measured in early June with a 0.5-inch diameter, 30° solid angle cone tip, hand-operated, recording penetrometer (Carter, 1967). Strength measurements were recorded to a depth of 24 inches at nine positions across one row (from a nontraffic midrow to a traffic midrow). These measurements were made at three locations in each sub-subplot. Data were digitized into the computer using the method described by Busscher et al. (1986b). Data were log transformed before analysis for normalization (Cassel and Nelson, 1979).

Cotton plant populations were determined by counting plants in 30 feet of one row in each sub-subplot on June 6. White bloom counts were made daily in July and August (Monday-Friday) on 6.8 feet of one interior row in each sub-subplot. Cotton was chemically defoliated on October 18 and two interior rows were harvested with a two-row spindle picker on November 9. Lint percent was calculated by saw-ginning a sample of seedcotton from each harvest bag. Lint yield was estimated by multiplying seedcotton yield by lint percent.

Analysis of variance was performed on all data. When sources of variation were significant at P=0.05, means were separated by computing a least significant difference at the P=0.05 level.

Results and Discussion

As stated previously, drought resulted in no cotton yield in the experiment in 1993. Total N applied in that year was 80 lb N/acre and the 1993-1994 rye winter cover produced abundant biomass because of the high amounts of residual N, especially in the conservation tillage treatment (Table 1). Winter weed production was similar to that in previous years (Bauer and Busscher, 1993) and was not affected by surface tillage treatment (Table 1).

Table 1. Winter cover biomass production.

Winter Cover	Tillage: Nondisked	Disked	Mean
	lb/A		
Fallow	1,017[1]	**1,412**	1,215
Rye	5,169	**3,579**	**4,373**

[1]LSD (0.05) for **comparing tillage means within a cover crop is** 651 **lb/A.**

Soil strength was similar for all in-row subsoiled plots, regardless of winter cover or surface tillage treatment. In the nonsubsoiled, nondisked plots, the soil disruption pattern from the subsoiling that occurred in 1993 was still evident in 1994. For those plots, the soil depth under the row where penetration resistance was 20 bars was about 11 inches, regardless of winter cover treatment (data not shown). Depth to 20 bars penetration resistance was also about 11 inches in the in-row subsoiled plots. These results are similar to those found by Khalilian et al. (1991). They reported that soil loosening from deep tillage with a paratill was evident 11 months after tillage when controlled traffic was used in a wheat/soybean doublecrop conservation tillage system.

For the nonsubsoiled, disked plots following winter fallow, soil depth to 20 bars resistance was uniformly 5.5 inches across the entire 38-inch row. This finding suggests that a hardpan was formed by the disking operation. The tillage-induced hardpan did not occur when rye was disked into the soil. Even though differences in soil strength occurred, abundant precipitation occurred throughout July, August, and September and deep tillage did not significantly influence any of the other measured variables.

No differences in flower production rate occurred in the disked treatment between the fallow and rye winter cover treatments (Figure 1, top). For both, peak bloom occurred about 65 days after planting. In the nondisked plots, flowering was delayed in the cotton seeded into the rye mulch (Figure 1, bottom). End of season plant mapping indicated that the delay in flowering was partially caused by the first sympodial branches being higher on the mainstem for the cotton grown in the rye mulch (data not shown).

Cotton yield did not differ between nondisked and disked treatments following winter fallow (Table 2). This result is in contrast to the first 2 years after plot establishment where the nondisked treatment yielded less than the disked treat-

Table 2. Effect of cover crops and tillage on cotton lint yield.

Winter Cover	Tillage: Nondisked	Disked	Mean
	lb/A		
Fallow	**1,264**[1]	1,080	1,172
Rye	1,000	1,200	1,100

[1] LSD (0.05) for **comparing tillage means within a cover crop is** 196 **lb lint/A.**

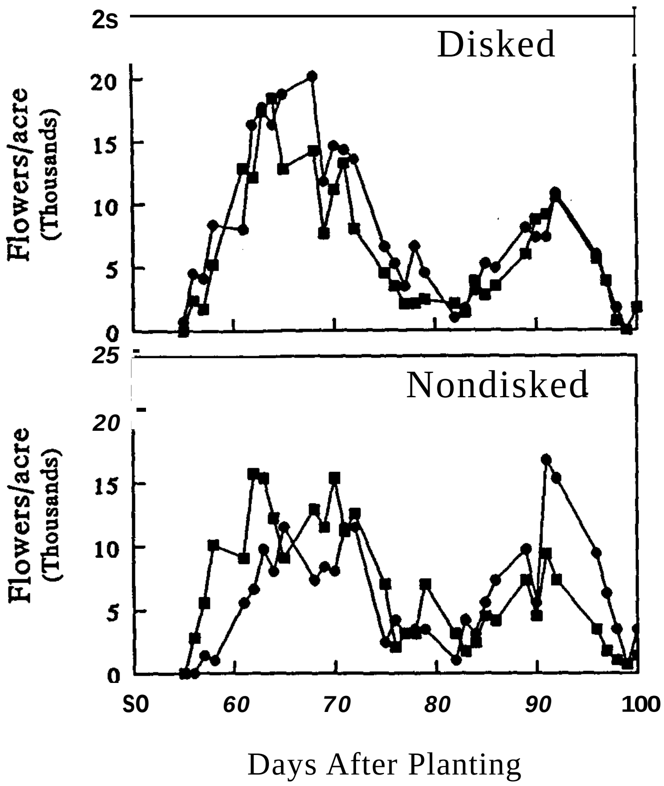

Figure 1. Flower production of cotton grown following winter cover treatments of fallow (squares) and rye (circles) in two tillage systems at Florence, SC.

ment (Bauer and Busscher, 1993). Following rye, the disked plots had greater yield than the nondisked (Table 2), which was partly caused by poorer stands in the nondisked plots (plant stands following rye were 1.3 and 2.0 plants per foot for nondisked and disked treatments, respectively). Also, although we did not quantify it, there was more boll rot in the plots with the rye surface residues, which probably accounted for some yield loss.

In summary, though differences in soil strength between treatment combinations occurred, they did not result in yield differences because of sufficient precipitation. Crop development was influenced by winter cover treatment without disking, but not with disking. The rye surface mulch delayed the initiation of reproductive growth. Although further verification is necessary, crop growth simulation models may require modification for application in situations where cotton is grown in fields with large amounts of surface residues.

Acknowledgment and Disclaimer

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References

Bauer, P.J., and W.J. Busscher. 1993. Effect of winter cover on soil moisture content in conventional and strip tillage cotton. pp. 8-10. *In* P.K. Bollich (ed). Proc. Southern Conservation Tillage Conference for Sustainable Agriculture. Monroe, LA.

Busscher, W.J., R.E. Sojka, and C.W. Doty. 1986a. Residual effects of tillage on Coastal Plain soil strength. Soil Sci. 141:144-148.

Busscher, W.J., R.E. Sojka, E.J. Sadler, and C.W. Doty. 1986b. Simplified data analysis for an inexpensive manual analogue penetrometer. Comput. and Electron. in Agric. 1:197-204.

Carter, L.M. 1967. Portable penetrometer measures soil strength profiles. Agric. Eng. 48:348-349.

Cassel, D.K., and L.A. Nelson. 1979. Variability of mechanical impedance in a tilled one hectare field of Norfolk sandy loam. Soil Sci. Soc. Am. J. 43:1450-455.

Hoskinson, P.E., and D.D. Howard. 1992. Influence of tillage on fruiting patterns of Deltapine 50 cotton. p. 603. In D.J. Herber and D.A. Richter (ed.) Proc. Beltwide Cotton Prod. Res. Conf. National Cotton Council, Memphis, TN.

Khalilian, A., C.E. Hood, J.H. Palmer, T.H. Gamer, and G.R. Bathke. 1991. Soil compaction and crop response to wheat/soybean interseeding. Transactions of the ASAE. 34:2299-2303.

Langdale, G.W., R.L. Wilson, Jr., and R.R. Bruce. 1990. Cropping frequencies to sustain long-term conservation tillage systems. Soil Sci. Soc. Am. J. 54:193-198.

Stevens, W.E., J.R. Johnson, J.J. Varco, and J. Parkman. 1992. Tillage and winter cover management effects on fruiting and yield of cotton. J. Prod. Agric. 5:570-575.

Population Dynamics of Insect Pests and Beneficial Arthropods in a Crimson Clover/Cotton Ecosystem with Conservation Tillage Cotton

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Abstract

Populations of the tobacco budworm, *Heliothis virescens* (F.), the cotton bollworm, *Helicoverpa zea* (Boddie), and their natural enemies were monitored April 27-Sept. 8, 1993 and April 21-Sept. 1, 1994 in crimson clover *(Trifolium incarnatum* L.) and a subsequent conservation tillage cotton *(Gossypium hirsutum* L.) crop. Treatments included winter cover (crimson clover and fallow) and midrow weed control method (herbicide-glyphosate and V-blade cultivator). Thrips were counted weekly May 18-June 17, 1994. Predaceous arthropods (mostly the bigeyed bug, *Geocoris* spp.) and parasitoids (Hymenoptera: Braconidae) were very active against *H. zea* and *H. virescens* populations in crimson clover during May. Pest population densities remained low through June in cotton. The peak in tobacco budworm/cotton bollworm population densities occurred during July. Bigeyed bugs, lady beetles, and ants were the most abundant predators. Densities of ants were highest in plots that had a clover cover and were not cultivated, and tobacco budworm/cotton bollworm egg reductions were detected in noncultivated plots. Egg parasitism by *Trichogramma* spp. was important in helping to reduce bollworm populations during August. Thrips numbers were low and highly variable among treatments with no clear patterns.

Introduction

Increased interest in conservation tillage has caused concern about the potential of insect pests and the efficacy of their natural enemies in these systems. Conservation tillage has the potential to control soil erosion and to help growers use energy more efficiently. The effects of conservation tillage on specific arthropods in cotton are important because of the relationship of some arthropods with the soil and with various cover crops such as crimson clover *(Trifolium incarnatum* L.).

The major lepidopterous pests in cotton in South Carolina belong to the tobacco budworm (TBW), *Heliothis virescens* (F.)/cotton bollworm (CBW), *Helicoverpa zea* (Boddie), complex. These pests overwinter as diapausing pupae in earthen cells as deep as 6 inches. Overwintered moths emerge largely during May through exit tunnels made by the prepupae the previous year (Neunzig, 1969). Throughout the cotton growing season, prepupae drop to the soil before pupation and tunnel to the depth of about one inch. There can be up to four generations per year in South Carolina cotton. Roach (1981a) reported that although greater numbers of moths emerged from conservation-tillage plots, *Heliothis/Helicoverpa* populations in conservation-tillage and plow-tillage plots in cotton had similar densities (Roach 1981b).

The impact of predaceous arthropods on TBW in cotton during early season in South Carolina has been determined (Greene et al. 1995). Beneficial arthropods helped reduce numbers of TBW, providing adequate control in early season. Conservation-tillage systems may alter pest and beneficial insect populations (All and Musick, 1986). As much as possible, we should avoid practices that interfere with biological control and utilize procedures that favor the biological potential of natural enemies so that minimal insecticide applications will be necessary.

The purpose of this study was to document seasonal occurrence and population densities of thrips, tobacco budworm/cotton bollworm (TBW/CBW), and their natural enemies in conservation tillage systems.

Materials And Methods

Research was conducted at the Pee Dee Research and Education Center near Florence, South Carolina. Cotton ('DES 119') was planted with a four-row no-till planter in 38-inch rows. Plots were 8 rows wide and 50 feet long. Treatments included winter cover (crimson clover and fallow) and midrow weed control method (herbicide-glyphosate and V-blade cul-

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tivator). Treatments were arranged in a randomized complete block design with a split plot arrangement. Winter cover was the main plot, and the midrow weed control method was the subplot. Crop management and treatment applications are described by Bauer et al., 1994. Insecticide treatments targeting TBW/CBW were applied July 21 (Larvin) and July 27 (Scout@), and August 12 (Asana) in 1993; no insecticides were applied during 1994 against these insect pests.

Eggs and larvae of TBW/CBW and their natural enemies were monitored and sampled during two growing seasons, 1993 and 1994. Samples were collected one **or** two times per week April 27-Sept. 8, 1993 and from April 21 through Sept. 1, 1994. Thrips were counted weekly May 18-June 17, 1994.

Larvae were collected from crimson clover during April and May using a heavy sweep net (14.75-in. diameter). Eggs and larvae were collected and population density estimates were recorded from the visual examination of 100 cotton plants per treatment once or twice per week. Predaceous arthropod populations were estimated by using a 15-quart dishpan (14 x 13 x 6 in.). The plants (2 meters per plot) were bent gently over and shaken into the dishpan in order to count predators.

Each collected larva was placed in a 30-ml plastic cup containing artificial diet (Greene et al. 1976). Eggs were transported to the laboratory and placed individually in size 0 gelatin capsules. Larvae and eggs were held at 26±2°C, 60±5% RH, and a 14:10 LD regimen and checked every 1 to 2 days for hatching, parasitoid emergence, pupation, and disease symptoms. Egg parasitoids were prepared and mounted on slides for identification. Adult parasitoids that emerged from pest larvae, along with their cocoons, were preserved in vials of 95% ethyl alcohol and identified by the senior author.

Results and Discussion

Insect pests

1993. Population density of TBW/CBW larvae was not determined in crimson clover. The peak population in TBW/CBW eggs occurred in cotton during late July 1993 with 84 eggs per 100 plants. Larval density reached only 2 per 100 plants. Percent composition of species is listed in Table 1.

1994. Thrips population densities during May and June 1994 are depicted in Figure 1. On May 23, population density peaked at less than 0.5 thrips per seedling. Insecticide applications are recommended when one or more thrips per plant are detected in the seedling stage. Through most of the sampling period, however, thrips numbers were highly variable among treatments with no clear patterns. Ruberson et al. (1995) reported that thrips populations were generally lower in reduced tillage (clover, strip-tilled) than in conventional tillage cotton. Economic threshold levels were not reached in either tillage system. The peak population density was less than 13 and 23 thrips per meter on July 29 and August 24 in conventional and reduced tillage, respectively. Thrips population densities are typically reduced in conservation tillage production systems relative to conventional ones (J. All, personal communication)

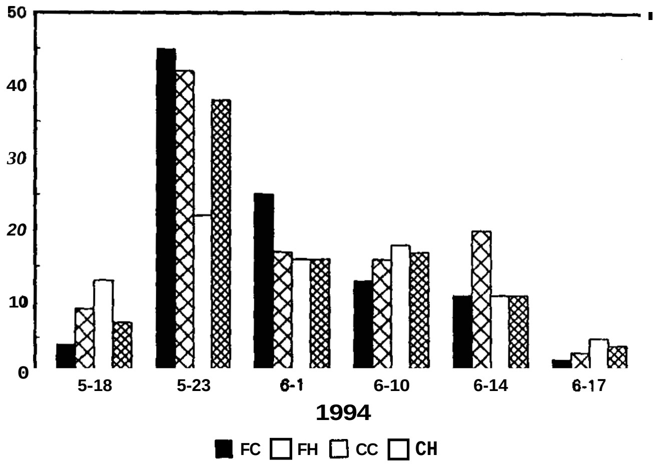

Figure 1. Population densities of thrips in fallow cultivated (FC), fallow herbicide (FH), clover cultivated (CC), and clover herbicide (CH) treated cotton. Florence, SC, 1994.

Egg numbers of TBW/CBW were low during June through the 6-leaf stage of cotton. Two peaks in egg densities are depicted in Figure 2. All plants were blooming at the time of occurrence of peak TBW/CBW population densities on July 25, and eggs were reduced in fallow, noncultivated (FH), conservation tillage plots. During August when bolls formed, egg densities were lower than during July.

Table 1. Percent composition of two lepidopterous species in crimson clover during May and cotton during June, July, and August 1993. Florence. SC.

	n	*Heliothis virescens*	*Helieoverpa zea*
May	153	35.3	64.7
June	48	19.2	20.8
July	211	25.6	74.4
August	78	<1.0%	99.6%

Predaceous Arthropods

1993. Beneficial arthropods were very active in crimson clover during the spring. During April, lacewings *(Chrysopa* spp.) were most prevalent, followed by lady beetles (Coccinellidae) and spiders (Araneida). The most prevalent predators during May 1993, were the bigeyed bugs (Geocoris spp.), followed by lady beetles, spiders, and nabids (Nabis spp.). Ants (Formicidae) were least prevalent.

During June, predators sampled with the dishpan reached a population density of 4.6 per m of row. Bigeyed bugs were most prevalent.

Predaceous arthropod populations peaked in midJuly

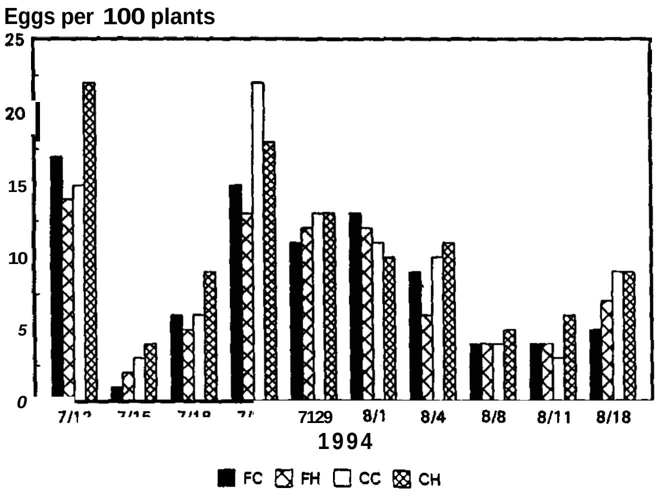

Figure 2. Population densities of tobacco budworm/cotton bollworm **eggs** in fallow cultivated (FC), fallow herbicide ((FH), clover cultivated (CC), and clover herbicide (CH) treated cotton. Florence, ***SC,*** **1994.**

reaching 9.2 per m of row. It appears that high numbers of bigeyed bugs helped to suppress the pest population but were not successful in maintaining egg densities below economic threshold levels. Insecticides were applied on July 21 and 27 and August 12.

1994. The most prevalent predators in crimson clover during April were lady beetles, followed by nabids and spiders. As in 1993, the bigeyed bug became the most prevalent predator from the maturing crimson clover during mid-May 1994.

During June when egg numbers of TBW/CBW were low, predators sampled with the dishpan reached a population density of 7.5 per m of row. Ants were the most abundant predators.

Numbers of predators peaked at 13 per meter of row on August 2 (Figure 3), and pests did not reach economic thresholds. Ants were most abundant (Figure 4), followed by lady beetles and spiders (Figures 5 and 6, respectively). Bigeyed bugs, hooded beetles, and nabids were also present (Figures 7, 8, and 9, respectively). It appears that fire ants may have been reduced in cultivated plots during early July. The V-blade cultivator ran 1.5-2.0 inches under the soil surface with little disruption of surface residue. The cultivator

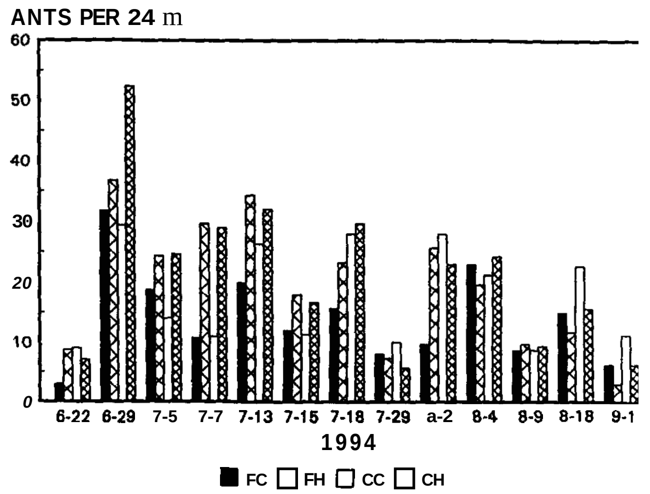

Figure 4, Population densities of ants in fallow cultivated (FC), fallow herbicide (FH), clover cultivated (CC), and clover herbicide (CH) treated cotton. Florence, SC, 1994.

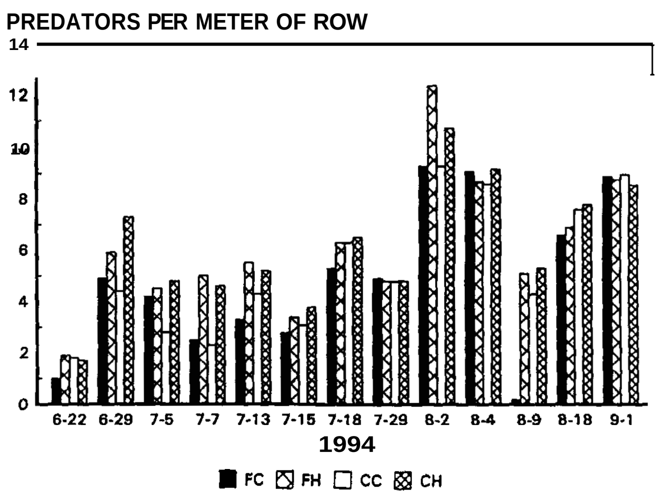

Figure 3. Population densities of predators in fallow cultivated (FC), fallow herbicide (FH), clover cultivated (CC), and clover herbicide (CH) treated cotton. Florence, SC, 1994.

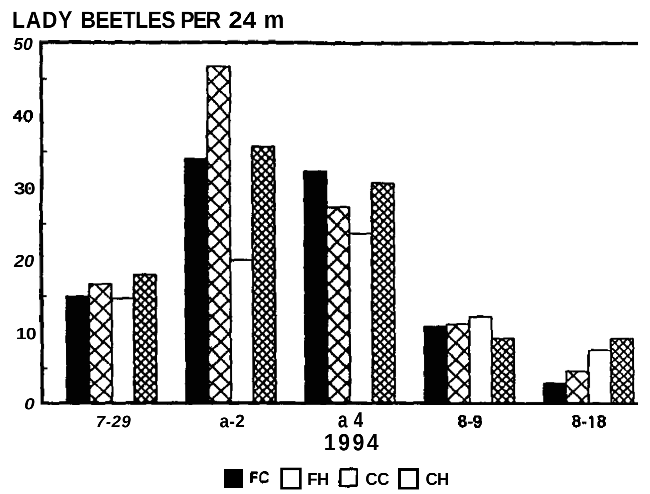

Figure 5. Population densities of lady beetles in fallow cultivated (FC), fallow herbicide (FH), clover cultivated (CC), and clover herbicide (CH) treated cotton. Florence, SC, 1994.

was utilized on June 13 and July 7 and 13. Ruberson et al. (1995) reported that there were more fire ants in a reduced tillage cotton field planted after clover as a cover compared with a conventional field of cotton.

Parasitoids

Parasitism of TBW/CBW larvae was high in crimson clover, reaching 66 and 33% during May of 1993 and 1994, respectively. Parasitoids included the braconid wasps *Cardiochiles* nigriceps Viereck, *Meteorus autographae* Muesebeck, and *Microplitis croceipes* (Cresson) both years. The braconid *Cotesia marginiventris* (Cresson) was detected only in 1993. Percentage of parasitism by various species is listed in Table 2. A eulophid wasp *Euplectrus* sp. occurred only in 1994. McCutcheon et al. (1981) reported that each of these beneficial wasps are active in agronomic crops later in the growing season. Crimson clover serves as an excellent host plant for beneficials to build up on.

Egg parasitism by *Trichogramma* spp. reached 30% by late July during both seasons, regardless of pyrethroid treatments applied 3 days prior to sampling during 1993. Egg parasitism

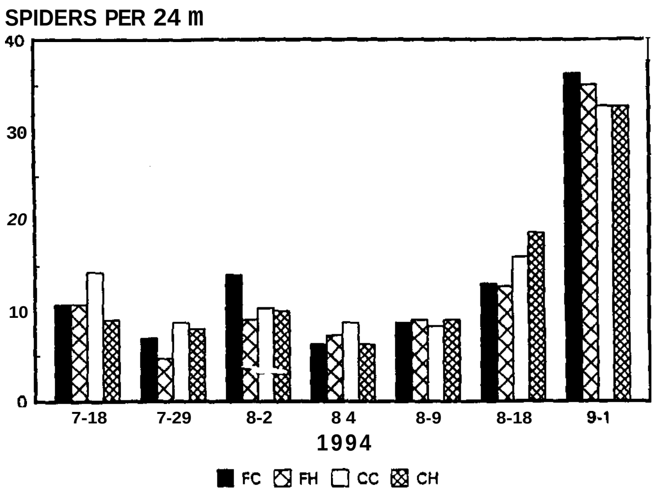

Figure 6. Population densities of spiders in fallow cultivated (FC), fallow herbicide (FH), clover cultivated (CC), and clover herbicide (CH) treated cotton. Florence, SC, 1994.

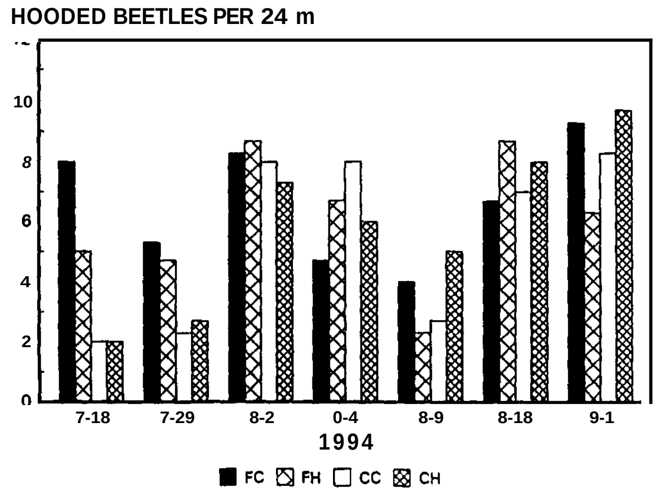

Figure 8. Population densities of hooded beetles in fallow cultivated (FC), fallow herbicide (FH), clover cultivated (CC), and clover herbicide (CH) treated cotton. Florence, SC, 1994.

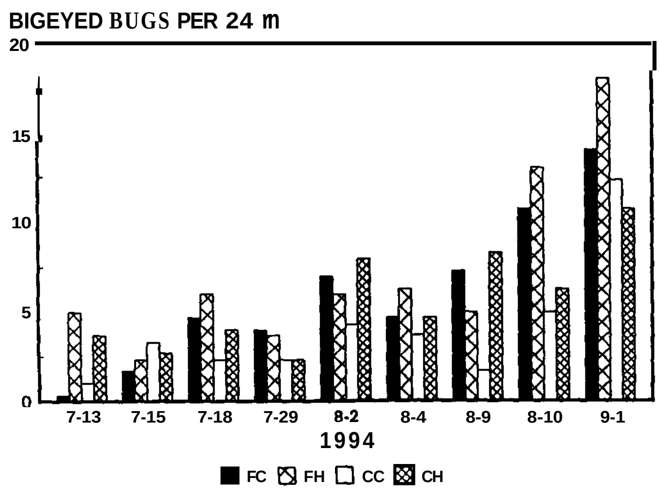

Figure 7. Population densities of bigeyed bugs in fallow cultivated (FC), fallow herbicide (FH), clover cultivated (CC), and clover herbicide (CH) treated cotton. Florence, SC, 1994.

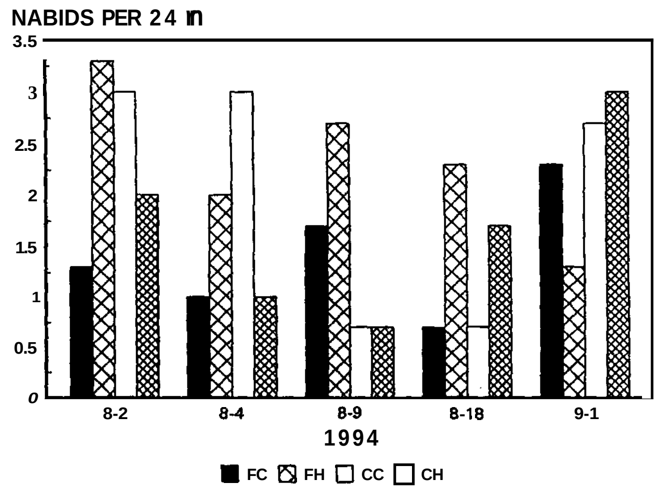

Figure 9. Population densities of nabids in fallow cultivated (FC), fallow herbicide (FH), clover cultivated (CC), and clover herbicide (CH) treated cotton. Florence, SC, 1994.

Table 2. Percent .parasitism by braconid wasps on budworm/bollworm larvae collected from crimson clover. 1993. Florence, SC.

	n	*Cotesia marginiventris*	*Cardiochiles nigriceps*	*Microplitis eroeeipes*	*Meteorus aufographae*
May 11	65	7.7	3.1	1.5	0.0
May 17	71	11.3	22.5	16.9	15.5
May 25	41	0.0	19.5	0.0	2.4
May 27	28	0.0	10.7	10.7	7.1
May 28	9	11.1	22.2	0.0	0.0

was high throughout August, reaching 42 and 70% in 1993 and 1994, respectively. *Tnchogramma* spp. remained active following an application of Asana on Aug. 12, 1993.

Parasitoids of TBW larvae collected from cotton included *Cardiochiles nigriceps* and *Cotesia marginiventns*. The latter was also reared from CBW. The tachinid fly, *Archytas marmoratus*, a larval-pupal parasitoid was reared from CBW.

Some differences in insect population densities were detected among treatments. Densities of ants were reduced in cultivated plots, and densities of TBW/CBW eggs were possibly reduced in non-cultivated plots as a result of this. These findings merit further investigation to determine the potential for pest insect suppression by beneficial arthropods in conservation tillage systems.

Acknowledgments and Disclaimer

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Literature Cited

All, J.N., and G.J. Musick, 1986. Management of vertebrate and invertebrate pests. *In* M. A. Sprague and G. B. Triplett (eds). No-Tillage and Surface Tillage Agriculture. pp. 347-387.

Bauer, P. J., J. G. Alphin, J. R. Frederick, and G. S. McCutcheon. 1994. Evaluation of a blade cultivator for conservation tillage cotton following crimson clover. *In* Proc. of the 1994 Southern Conservation Tillage Conf. for Sustainable Agric., June 7-9, Columbia, SC.

Greene, G. L., N. C. Leppla, and W. A. Dickerson. 1976. Velvetbean caterpillar: a rearing procedure and artificial medium. J. Econ. Entomol. 69: 487-488.

Greene, J. K., G. S. McCutcheon, S. G. Turnipseed, and M. J. Sullivan. 1995. The impact of beneficial arthropods on cotton insects in South Carolina with and without early season control of the tobacco budworm. Beltwide Cotton Conf., Jan. 7-10, San Antonio, TX.

Neunzig, H. H. 1969. The biology of the tobacco budworm and the corn earworm in North Carolina with particular reference to tobacco as a host. N. C. Agr. Exp. Sta. Tech. Bull. No. 196: 1-76.

McCutcheon, G. S. and S. G. Turnipseed. 1981. Parasites of lepidopterous larvae in insect resistant and susceptible soybeans in South Carolina. Environ. Entomol. 10:69-74.

Roach, S. H. 198la. Emergence of overwintered *Heliothis* spp. moths from three different tillage systems. Environ. Entomol. 10:817-818.

Roach, S. H. 1981b. Reduced vs. conventional tillage practices in cotton and tobacco; a comparison of insect populations and yields in northeast South Carolina, 1977 - 1979. J. Econ. Entomol. 79: 688-695.

Ruberson, I. R., W. J. Lewis, D. J. Waters, O. Stapel, and P. B. Haney. 1995. Dynamics of insect populations in a reduced-tillage, crimson clover/cotton system. Beltwide Cotton Conf., Jan. 7-10, San Antonio, TX.

Weed Management in No-Till Cotton Utilizing a Hooded and a Post-Directed Sprayer

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Introduction

No-tillage cotton production continues to increase across the Cotton Belt. Acreage in Tennessee has gone from 85,000 acres in 1992 to 155,000 acres in 1993 (Anonymous, 1993). This is 14 and 24% of the total cotton acreage in the state, respectively. These numbers reflect an increased acceptance by producers and a general shift to no-till production. New practices are typically accepted if they offer advantages over current systems.

Shelton and Mote (1989) found that no-till cotton production reduced soil losses by 2 tons/A when compared to conventional tillage soybeans. Reduction in soil loss is a fundamental advantage of a no-till system. Producers participating in government programs were required by the 1990 Farm Bill to be in compliance with regard to soil erosion on land classified as highly erodible by Jan. 1, 1995. No-till conceivably would enable producers to continue farming land while meeting compliance requirements.

Yields of no-till cotton have been competitive with those of conventional tillage across the Cotton Belt. Bradley (1993) reported no-till cotton averaged 910 lb lint/A versus 894 Ib lint/A in conventional tillage over a 10-year period in Tennessee. In a separate study, Harmon et. al. (1989) found average no-till cotton yields over 4 years to be 41% greater than with conventional tillage in the Texas High Plains. No-till cotton yields were greater than conventional each year of this study.

Weed control systems differ in no-tillage when compared to other tillage systems. Conventional tillage relies on cultivation in addition to herbicides for weed control. This allows producers to band preemergence herbicides over-the-row and cultivate between rows for weed control. Banding of herbicides may be an option in no-till, however cultivation may not be possible or practical. Preemergence broadcast applications afford two disadvantages over banding. Cost is the major factor of consideration. Producers can reduce application cost by half when herbicides are banded (Hudson, 1993).

The second disadvantage is more total herbicide introduction into the environment. Driven by public perception, policies are demanding total usage of herbicides be reduced. Food Systems 2002 is a Canadian research initiative established in 1988, which promotes a reduction in total pesticide usage in Canada 50 percent by the year 2002 (Swanton and Weise, 1989). The United States Department of Agriculture and the Environmental Protection Agency have signed an agreement that will create a program to develop nonchemical pesticides. The goal is to create alternative pest management strategies. This followed announcement by the Clinton Administration to initiate Integrated Pest Management systems on 75% of farm acreage by the year 2000.

The objective of this experiment was to compare herbicide systems for weed control in no-tillage cotton utilizing a hooded and a post-directed sprayer. Systems were evaluated for weed control and cost effectiveness.

Materials and Methods

Preemergence Applications

The experiment was conducted in 1994 on a Loring silt loam soil at Milan, Tennessee. Glyphosate at 1.0 lb ai/A plus 0.5% v/v nonionic surfactant (NIS) was applied on April 18, using a Spra-Coupe sprayer calibrated to deliver 20 gpa. 'Deltapine DPL 5415' cotton seed was planted at 15 lb/A on April 26. Individual plots consisted of four 40-inch rows hand-trimmed to 30 feet in length. Treatments were replicated five times.

Aldicarb insecticide at 0.5 lb ai/A and 0.8 lb ai/A PCNB plus 0.2 lb ai/A etridiazole plus 0.80 lb ai/A disulfoton fungicide was applied into the seed furrow.

Preemergence banded treatments of 0.31 lb ai/A paraquat dichloride plus 1.2 lb ai/A fluometuron plus 0.75 Ib ai/A pendimethalin plus 0.5 % v/v NIS were applied to treatments 1, 2, 3, 4, 5, 6, 7, and 9. Preemergence banded treatments were applied with a tractor-mounted small plot sprayer calibrated to deliver 20 gpa. Band width was 20 inches applied directly over the row. Treatment 8 received a preemergence broadcast application of 0.31 lb ai/A paraquat dichloride plus 1.2 lb ai/A fluometuron plus 0.75 lb ai/A pendimethalin plus 0.5% v/v NIS applied with a tractor-mounted small plot sprayer calibrated to deliver 20 gpa (Table 1).

Cool, wet weather favored seedling disease and contributed to an unacceptable stand. Paraquat dichloride at 0.31 lb ai/A plus 0.5% v/v NIS was applied in 20 gpa to kill existing cotton and other vegetation. 'Chembred CB 1135' was planted on May 12 at a seeding rate of 15 lb/A. Seeds were plant-

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Table 1. Preemergence treatments on no-till cotton.

PRE BAND	20-in. Band*	Paraquat	0.31 lb ai1A
		Fluometuron	1.20 lb ai1A
		Pendimethalin	0.75 lb ai1A
PRE BDCST	Broadcast*	Paraquat	0.31 Ib ai1A
		Fluometuron	1.20 Ib ai1A
		Pendimethalin	0.75 lb ailA

*Preemergence treatments included .25 % v/v nonionic surfactant.

ed directly into previous rows. Seed furrow applications of fungicide and insecticide were repeated as previously mentioned.

Postemergence Stage I Application

A Custom Ag Products, Inc., Redball™ chemical cultivation spray hood was used for postemergence, hooded applications. The unit consisted of three 28-inch-wide hoods for the three inside row middles and two 20-inch-wide spray hoods for the outside middles. The 28-inch hoods contained 3 nozzles per hood, and 20-inch hoods contained 2 nozzles per hood. Adjustable spray nozzles mounted on the outside, trailing edge of hoods were used for postemergence directed applications. Cone tanks (15 gal) mounted on the sprayer tool bar delivered spray solutions through two power takeoff (PTO) driven six-roller pumps. A post-directed sprayer with two nozzles per row and two nozzles between each row was utilized on treatment 8. This treatment received post-directed applications only.

Postemergence hooded or directed applications were first made on June 7. All applications were made according to cotton growth stages (Table 2). Cotton stage was 2- to 4-leaf, 2- to 4-inches tall. Weed species present were smooth pigweed *(Amaranthus* hybridus) and tumble pigweed *(Amaranthus albus)* at 1 per square foot, 0.5- to 6-inches tall. Treatments 3 and 4 were applied through the hooded sprayer utilizing the hoods and post-directed nozzles simultaneously. Paraquat dichloride at 0.31 lb ai/A plus 0.8 lb ai/A cyanazine plus 0.5% v/v NIS were applied under hoods while 1.0 lb ai/A fluometuron plus 2.0 lb ai/A MSMA were applied under cotton through directed nozzles. Treatment 5 received 0.31 lb ai/A paraquat dichloride under hoods only. Treatment 6 received 0.75 lb ai/A glyphosate under hoods only. Treatment 7 received 0.06 Ib ai/A pyrithiobac over-the-top of row in a 20-inch band. In a secondary separate application, 0.75 lb ai/A glyphosate was applied under hoods to treatment 7. Treatment 8 received 1.0 lb ai/A fluometuron plus 2.0 lb ailA MSMA post-directed with the previously described post-directed sprayer.

Postemergence Stage II Application

Second cotton stage postemergence applications were made when cotton was 5- to 6-leaf, 6 to 9 inches tall. Pigweed spp. continued to be the predominant weed present and plants were 2 to 18 inches tall.

Treatments 1 and 2 received their first postemergence applications. Paraquat dichloride at 0.31 Ib ai/A was tank mixed with 0.8 lb ai/A cyanazine plus 0.5% v/v NIS and applied under the hoods to treatment 1. A post-directed application of 1.0 lb ai/A prometryn plus 2.0 lb ai/A MSMA was made simultaneously to treatment 1. Treatment 2 received 0.75 lb ai/A glyphosate plus 0.5% v/v NIS under the hoods, while 1.0 Ib ai/A prometryn plus 2.0 lb ai/A MSMA were applied through post-directed nozzles.

Table 2. Preemergence and postemergence treatments for weed control in no-till cotton.

Tmt No.	Treatment	Appl. Timing	Appl. Stage in.	Appl. Rate lb ai/A	Pigweed Control %	Lint Yield lb/A	Herbicide Cost $/A
1	PREBAND	Pre	0		78	749	36.00
	Paraquat**	Hooded	6-9	0.31			
	Cynazine	Hooded	6-9	1.00			
	Prometryn	Directed	6-9	1.00			
	MSMA	Directed	6-9	2.00			
2	PREBAND	Pre	0		*64*	703	36.00
	Glyphosate**	Hooded	6-9	0.75			
	Prometryn	Directed	6-9	1.00			
	MSMA	Directed	6-9	2.00			
3	PREBAND	Pre	0		90	975	40.00
	Paraquat**	Hooded	2-4	0.31			
	Cyanazine	Hooded	2-4	0.80			
	Fluometuron	Directed	2-4	1.00			
	MSMA	Directed	2-4	2.00			
	Paraquat**	Hooded	6-9	0.31			
4	PREBAND	Pre	0		82	923	43.00
	Glyphosate**	Hooded	2-4	0.75			
	Fluometuron	Directed	2-4	1.00			
	MSMA	Directed	2-4	2.00			
	Glyphosate**	Hooded	6-9	0.75			
5	PREBAND	Pre	0		82	890	31.00
	Paraquat**	Hooded	2-4	0.31			
	Paraquat**	Hooded	6-9	0.31			
6	PREBAND	Pre	0		75	797	39.00
	Glyphosate**	Hooded	2-4	0.75			
	Glyphosate**	Hooded	6-9	0.75			
7	PREBAND	Pre	0		61	797	?
	Pyrithiobac**	Banded	2-4	0.06			
	Glyphosate**	Hooded	2-4	0.75			
8	PREBDCST	Pre	0		95	787	68.00
	Fluometuron	Directed	2-4	1.00			
	MSMA	Directed	2-4	2.00			
	Cyanazine	Directed	6-9	0.80			
	MSMA	Directed	6-9	2.00			
9	PREBAND	Pre	0		0	**410**	**25.00***
	Untreated Check						
				LSD (0.05)	18	228	

*The untreated check received a 20-inch preemergence band treatment only.

**Applications included .25% v/v nonionic surfactant (not included in cost analysis).

Treatments 3, 4, 5, 6, and 8 received a postemergence sequential application at the second growth stage. Paraquat dichloride plus NIS were applied under the hoods at 0.31 lb ai/A and 0.5% v/v, respectively, to treatments 3 and 5. Glyphosate at 0.75 lb ai/A plus 0.5% v/v NIS were applied under the hoods to treatments 4 and 6. Cyanazine at 0.8 lb ai/A plus 2.0 lb ai/A MSMA were applied with the post-directed sprayer to treatment 8.

Results and Discussion

Percent pigweed control and lint yields are listed in Table 2. These data were recorded 30 days after the 6- to 9-inch cotton stage applications. All stage 1 and/or stage 2 applications improved pigweed control and cotton lint yield over the pre-band treatment. The standard (treatment 8) broadcast preemergence application followed by two post-directed applications resulted in some of the highest yields. Lint yields with banded preemergence herbicides followed by hooded applications were similar to the standard.

There were notable trends in weed control among treatments without significant differences. Applications of glyphosate and paraquat applied at 6- to 9-inch cotton did not perform as well as sequential treatments. Paraquat alone and tankmixed with cyanazine under the hoods controlled pigweed better than glyphosate alone. Glyphosate under the hoods and a post-directed application in the row improved control over glyphosate applied under the hoods alone. Cotton injury was less than 10 percent for all treatments (data not shown).

A complete cost analysis was not performed for the treatments; however herbicide costs were compared (Table 2). Cost of hooded programs, which included a banded preemergence application, ranged from $31 to $43/A. The post-directed "standard" program, which included a broadcast preemergence application (treatment 8), cost was $68/A. Differences in cost can be attributed to the banded versus broadcast preemergence applications.

Literature Cited

Anonymous. 1993. Tennessee 1993 tillage systems. Tenn. Ag. Stat. Service, Nashville, TN.

Bradley, J.F. 1993. Success with no-till cotton. pp. 46-48. *In* M.R. McClelland, T.D. Valco and R.E. Frans (ed.) Conservation-tillage systems for cotton. Ark. Agric. Exp. Stn. Spec. Rep. 160.

Harmon, W.L., G.J. Michels and A.F. Wiese. 1989. A conservation tillage system for profitable cotton production in the Central Texas High Plains. Agron. J. 81:615-618.

Hudson, E.H. 1993. Economic considerations of no-tillage farming. AE & RD Info. #49, The University of Tennessee Agricultural Extension Service. pp. 24-25.

Shelton, C.H., and C.R. Mote. 1989. Soil erosion and related water quality. Tenn. Farm and Home Sci. 152:26-31.

Swanton, C.J., and S.F. Weise. 1991. Integrated weed management: The rationale and approach. Weed Technol. 5:657-663.

Compliance and Cotton Tillage Trends

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The 1985 Farm Bill, The Food Security Act, required that a conservation compliance plan must exist on Highly Erodible Lands (HEL) if a producer wishes to receive USDA benefits. These plans were to be developed by January 1, 1990, and be fully implemented by January 1, 1995. The HEL designation was calculated for each soil by multiplying those factors of the Universal Soil Loss Equation and the Wind Erosion Equation that are unaffected by management, and dividing by the soil loss tolerance. If the resulting erosion index was eight or above, the soil map unit was designated HEL. If one-third of the field, or 50 acres, were HEL soil map units, then the field was designated highly.erodible and a compliance plan was required.

The climate, growing conditions, and soils are different in each cotton-growing region. The conservation and management alternatives an individual farmer chose also varied based on his management style and individual operation. The available options, therefore, varied.

Structural practices are an option anywhere if the potential for water erosion is a concern and the soil permits construction. Examples of these practices are terraces, grassed waterways, and water and sediment control basins. Associated with terraces is contour farming, a cultural operation which helps divert water around the slope at nonerosive velocity.

Generally, farmers chose some form of vegetative management as the major part of their compliance plan. The Conservation Technology Information Center annually conducts a survey to determine the acres of major crops planted into different residue levels and the forms of conservation tillage that are used. The three residue levels are 0 to 15%, 15 to 30%, and more than 30% of the soil surface covered. Those acres in the category of more than 30% are further divided into three recognized forms of conservation tillage; i.e., no-till, ridge-till, and mulch-till.

In the cotton-growing region from Texas to North Carolina, the total acres for all crops planted into the lower residue levels have steadily decreased since 1990. Although mulch-till has increased somewhat, the most dramatic increase has been in no-till in the Southeast and Midsouth. In the Southern Plains states, the 15 to 30% level and mulch-till categories had the greatest increase.

In the Southeast, a popular practice is contour stripcropping. This practice involves cotton, or other row crop, grown on the contour and alternated with an equal width strip of sod or close growing crop such as wheat. The benefit here is that water from the row crop enters the sod or close-grown crop in a sheet flow. Some of the sediment is filtered out, and some of the water is slowed, which allows more time for water to infiltrate. Crop rotation, along with some form of residue management, is a part of most compliance plans. An example is cotton planted into last year's corn or wheat residue that covers 30% or more of the soil surface.

Each year, a sample of tracts is reviewed to determine the status of progress toward implementation of the conservation compliance plan. This review includes all cropped land regardless of the crop grown. Therefore, the figures include other crops as well as cotton.

Although the final 1994 Status Review results have not been published, preliminary data as of November 1994, show that in the Southeast, 3,328 tracts were checked and that 1,987, or 60%, had fully applied systems, while 31% were actively applying an approved system. Nine percent were not actively applying an approved system.

In the Midsouth, residue management is primarily the choice of producers. Where crop rotations are involved, corn or other residue from the previous year is managed to leave 30% of the ground covered.

Where continuous cotton is grown, two kinds of systems are generally employed. On flat to gently sloping land, leaving alone the previous year's cotton stalks, or leaving stalks with volunteer winter weeds will adequately protect the soil surface. The weeds are then killed prior to planting, and cotton is no-tilled directly into the cover. This system, commonly referred to as stale seedbed, is a cost-effective method of controlling erosion. On land that is more sloping, a cover crop is usually required to provide adequate protection. The cover crop is either drilled, or broadcast seeded early enough for germination and growth prior to cold weather. The cover crop is killed in the spring prior to planting cotton.

A status review in the Midsouth region was made on 1,837 tracts. The results show that 941, or 51%, had fully applied systems. There were 15 percent that were not actively applying an approved system.

In the Southern Plains states, both wind and water erosion can occur. As a general rule, vegetative treatment that is effective for water erosion control is also adequate for wind erosion control. An exception to this is where water concentrates, thus requiring additional help to control washing.

Where crop rotations are performed, residue from previous crops can be managed to control erosion. Cover crops are usually grown where continuous cotton is grown, particularly on irrigated land. On nonirrigated land where continuous cotton is grown, wind stripcropping, ridging, and/or surface roughening is usually practiced.

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In the Southern Plains states, of the 2,417 tracts that have had a status review, 1,913, or 79%, were found to have a fully applied system. Three percent, or 76 in number, were found to be not actively applying an approved system.

In summary, conservation tillage for cotton is increasing. A high percentage of compliance plans relied on some form of vegetative measures such as crop rotations, cover crops, and crop residue use for the key treatment.

A large majority of farmers are voluntarily applying an approved system.

No-Till, No-Herbicide Systems for Production of Transplanted Broccoli

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Introduction

Weed control has been a severe problem in no-till (NT) vegetable systems because cultivation and plastic mulches are normally not used in untilled (NT) soils. Since chemical weed control in vegetables is often ineffective or environmentally unfriendly, integrated weed management (IWM) systems are generally required. In IWM, all aspects of crop production are considered to both reduce the effect of weed interference on crop yield and minimize impacts of crop production on the environment (Swanton and Weise, 1991). Weed management methods are commonly divided into four overlapping categories: cultural, biological, mechanical, and chemical (Forcella and Burnside, 1994). Combinations of two or more of these methods, especially when considering sustainable weed management, are applications of IWM.

As vegetable and tobacco production moves toward more sustainable systems, cultural weed control methods should play a major role, and in many cases should predominate in IWM systems. Cultural weed control exploits the ecological principles of plant competition in which the first plants to occupy an area or space have a competitive advantage over those that follow (Wicks et al., 1994). Thus, effective cultural weed control practices are those that favor growth of the planted crop over germination and growth of intruding species (weeds). Cultural weed control practices can be conveniently divided into two strategies: (a) those that enhance rapid growth and canopy closure of the planted crop, and (b) those that inhibit or delay germination, emergence and growth of weeds.

The extent to which cultural practices can predominate in IWM systems is highly dependent upon the vegetable species grown and crop establishment method used. Transplanting a fast-growing cole crop such as broccoli in narrow multiple-row beds using large, vigorous transplants results in rapid canopy closure in the bed area, minimizing or even eliminating the need for herbicides (Infante and Morse, 1995).

No-till production systems using dense, evenly distributed, persistent cover crop residues minimize the need for herbicides and optimize the conservation of soil and water (Morse, 1993). Achieving dense, uniform (before and after transplanting) persistent crop residues necessitates (a) proper establishment of recommended cover crops; (b) providing adequate growth inputs (water, nutrients and edaphic factors) and growing time to maximize cover crop biomass and quality (low weed levels and maturation of the cover crop tissues); and (c) effective establishment of the transplanted crop into the heavy killed mulch with minimal disturbance of surface residues and surface soil. Mechanical killing the cover crops has two distinct advantages over using contact herbicides: (a) because herbicides are not used, negative environmental impacts are reduced; and (b) cover crops can be killed just before planting, which maximizes the growth potential and maturation of the residues. Dense, mature plant residues persist longer throughout the growing season, which increases weed suppression and conservation of soil and water (Hoffman et al., 1993). Since a relatively high percentage of high-value transplanted crops are irrigated, potential soil moisture depletion problems from drought prior to planting are negated. Flail mowing and rolling can effectively kill mature cereal rye (*Secale cereale* L.), hairy vetch (*Vicia villosa* Roth), mixtures of hairy vetch and rye, crimson clover (*Trifolium incarnatum* L.), and wheat (*Tnticum* ***aestivum*** L.) (Dabney and Griffeth, 1987; Dabney et al., 1991; Hoffman et al., 1993).

Using the Subsurface Tiller Transplanter (SST-T) (Morse et al., 1993) to effectively set vegetable and tobacco transplants in mechanically-killed, heavy residues enhances the potential of reducing or even eliminating the use of chemical herbicides for production of transplanted row crops. Both cultural-method strategies are favorably affected in the SST-T/NT, heavy-residues system. Improved stands and rapid canopy closure (Morse, 1995) and persistence of uniform, dense residue ground cover intensify the competitive advantages of the transplanted crops over weed growth.

The objectives of this study were (a) to assess the effectiveness of flail mowing and rolling annual cover crops on weed suppression and persistence of killed cover crop residues, and (b) to determine the cover-crop and weed-management effects on yield of NT broccoli.

Materials and Methods

Field experiments were conducted in the fall of 1994 at the Virginia Polytechnic Institute and State University Kentland Agriculture Research Farm, Blacksburg. The soil was a Hayter loam (fine-loamy, mixed, mesic, Ultic Hapludaf), with a pH of 6.4. The experimental design was a split-split plot with four replications. Main plots (20 x40 ft) were cover crops:

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soybeans (S), buckwheat (B), and foxtail millet (FM). Subplots (10 x 40 ft) were chemical weed control: herbicide (H) applied on August 19 and control (no herbicide). Sub-subplots (5 x 40 ft) were cover crop residue management methods: flail mowing (F) and rolling (R), done on August 23.

On May 31, 1994, soybeans *(Glycine max* L.), buckwheat *(Fagopyrum saggitatum* Grlib.), and foxtail millet *(Setaria italica S L.)* were drilled in rows 7 inches apart at a rate of 75, 120, and 45 lb/acre, respectively.

On June 23, 1994, granular fertilizer was surface broadcast with (in lb/acre) 50N-22P-42K in buckwheat and foxtail millet plots and with ON-22P-42K in soybean plots. All plots were irrigated with a solid-set, overhead-sprinkler system during times of prolonged soil-moisture deficits.

Herbicide plots (H/F and H/R) were sprayed on August 19 with a tank mixture of l,l'-dimethy1-4-4'-bipyridiniumion (paraquat) at 0.5 lb ai/A and 2-chloro-l-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene (oxyfluorofen) at 0.5 lb ai/A.

Designated plots were flail mowed (F and H/F) or rolled (R and H/R) just prior to transplanting broccoli on August 23. Flail mowing was done with a reverse-rotor Alamo-Mott (74 inches wide, weight 850 pounds). Rolling was accomplished by pulling the disengaged Alamo-Mott flail mower across the plot. Only one pass was used for both flail mowing and rolling.

At transplanting and again on October 25, cover crop dry weight was determined by taking 5.4-ft^2 samples from each plot and drying them at 158 °F for 2 weeks. Cover crop persistence was determined by calculating the percentage of cover crop remaining on October 25 [(DW remaining x lOO)/DW at transplanting].

Bareroot 'Emperor' broccoli *(Brassica oleracea* L. var. italica) transplants were set on August 23 with the Subsurface Tiller-Transplanter (SST-T) (Morse et al., 1993). Granular fertilizer was surface banded at planting 3 inches from both sides of each row with (lb/acre) 85N-36P-141K-2B, using the SST-T. All plots were sidedressed by hand with NH_4NO_3 at 50 lb N/acre on September 8 and again on September 30.

To ensure a complete stand, transplants that did not survive were replaced by hand. Sprinkler irrigation was used at all sites throughout the growing season to minimize soil stress. Pesticides were applied at planting and at regular intervals thereafter, according to the Virginia Commercial Vegetable Production Recommendations (Virginia, 1994). One twin row (16,200 plants/acre) was planted in each sub-subplot. Rows were spaced 18 inches apart and 42 inches between twin rows (5 feet center to center); in-row spacing was 16 inches between plants. A total of six harvests were taken at weekly intervals, beginning October 13. Immediately after harvest, heads were cut to a length of 7.5 inches and fresh weights were recorded. Weed samples (5.4 ft^2) were taken between the twin rows on October 25 and dried for 2 weeks at 158 °F. The Statistical Analysis System (SAS) was used to perform all statistical analysis procedures (Scholtzhauer and Littel, 1987). Duncan's multiple range test was used for mean separation. Percentage data for cover crop persistence were analyzed after arcsine transformation.

Results and Discussion

Cover Crop Growth and Persistence

At transplanting, above-ground biomass was 4.1, 2.5, and 3.6 tons/acre for soybeans, buckwheat, and foxtail millet, respectively. Stand establishment was excellent for all cover crops. Since no preemergent herbicides were used, weeds germinated and grew along with the cover crops. However, cover crops outgrew and eventually smothered most weeds, except redroot pigweed *(Amaranths retroflexus* L.), which survived somewhat in soybean plots (5 % of the total biomass was pigweed).

At broccoli transplanting (12 weeks from seeding the cover crops), buckwheat had flowered and developed viable seed, foxtail millet had flowered and set immature seed, and soybeans were in early flowering. All cover crops were effectively killed by mowing or by the paraquat/oxyfluorfen treatment. One week after rolling, cover crops and most weeds were killed and lying prostrate over the ground, except in the soybean plots. Most of the redroot pigweed and some of the soybean residues were still green after one week in the rolled soybean plots. Redroot pigweed plants were not totally flattened in some areas, requiring hand chopping to minimize shading of the broccoli transplants. Regrowth did not occur in the millet and buckwheat plots and soybean greening did not become a yield-limiting factor, probably because rapid canopy closure within the broccoli twin rows smothered soybean regrowth.

In IWM systems, weed growth only limits growth of the planted crop when competition for available resources occurs. In the soybean plots, moisture, nutrients, and light interception apparently were adequate and did not limit broccoli growth, even though the soybean and redroot pigweed plants were not totally killed. Yield-limiting levels of growth inputs did not occur in rolled soybean plots because recommended nutrients and water were maintained in the root zone of the broccoli plants by irrigation and nitrogen sidedressings and shading was prevented by using narrow, twin-row plant arrangement. Rolling for transplanted NT row crops appears to be a viable residue management and cultural weed control technique when practiced on mature, annual cover crop species that are not heavily contaminated with large annual or perennial weeds.

Although increasing cover crop persistence can improve weed suppression (Hoffman et al., 1993), there is little research data evaluating methods for increasing residue persistence. Data in this study illustrate three distinct factors that increase residue persistence (Table 1).

First, cover crop species was a major factor, with foxtail millet being nearly double that of soybeans or buckwheat. The high C/N ratio (Aref Abdul-Baki, unpublished data) of

Table 1. Main effects on cover crop persistence, 1994.

Treatment	Cover crop persistence (%)[z]			Significance
	Soybean	Buckwheat	Foxtail millet	
Cover crop	33b[z]	30b	52a	***
	Herbicide	No herbicide		
Chemical weed control	33	43	**	
	Rolling	Flail mowing		
Residue management	47	29	***	

'Percentage cover crop residues remaining on October 25, 1994 (9 weeks after transplanting).

[z]Mean separation among cover crops by Duncan's multiple range test at $P \leq 0.05$. NS, **, *** F-test nonsignificant at $P \leq 0.05$ or significant at $P \leq 0.01$ and 0.001, respectively. There were no interactions among treatments ($P \leq 0.05$).

foxtail millet compared to soybeans and buckwheat probably accounts for this persistence difference among species.

Second, rolling retarded mineralization of cover crop tissues (improved persistence), compared to flail mowing. Rolling tends to layer and thus expose less residue surface area in contact with the soil compared to flail mowing, which shreds residues into small pieces (Dabney et al., 1991). Also, rolling leaves the plant intact longer than mowing, resulting in continued metabolism and delayed cellular degradation.

Third, not killing the cover crops (no herbicides) prior to rolling or mowing delayed breakdown of residue tissues. Of utmost importance, there were no interactions among treatments—i.e., treatment effects were additive. The most persistent plots (66%) were unsprayed (no herbicide), rolled foxtail millet; while the least persistent (17%) was herbicide-treated, flail-mowed buckwheat.

Weed Biomass

Weed growth was probably not a yield-limiting factor in any treatment. Weed biomass was low, averaging 263 pounds per acre dry weight and did not differ among treatments (data not shown). The high level of weed suppression can be attributed to several factors.

First, dense, uniform surface residues present at planting were maintained relatively intact Over the research plots. In previous experiments at the Kentland Agriculture Research Farm, Infante and Morse (1995) showed that weed suppression was greater in NT plots than with conventional tillage (CT). The high-clearance design of the Subsurface Tiller-Transplanter (SST-T) used in this study enabled effective broccoli transplanting with minimal disturbance of surface soil and surface residues (Morse et al., 1993). The SST-T functioned better in the rolled cover crops than flail mowed. Intact residues, rolled or oriented in the same direction that the SST-T traveled, resulted in greater transplanting efficiency compared to mowed residues, which showed some hairpinning and clogging of residues behind the shank of the SST. Hairpinning and clogging conceivably could be serious problems in heavy, mowed residues, particularly in wet, spongy soils.

Second, transplanting into a "stale seedbed" resulted in less weed seed germination than planting into freshly-tilled CT fields (Standifer and Beste, 1985). The stale seedbed technique is a form of limited tillage normally applied to plow-disk systems in which a flush of new weed seedlings germinating after tillage is killed with chemicals prior to planting. In like manner, the soil surface underneath a cover crop becomes a stale seedbed and, if left undisturbed after planting, will normally have less viable weed seeds than if tilled prior to transplanting.

Third, narrow twin rows facilitate rapid canopy closure within the twin-row areas (Forcella and Burside, 1994). In this study, in-row weed biomass was virtually held to zero because shading smothered the germinated weed seedlings. Infante and Morse (1995) and Serage (1993) showed similar results, with weed biomass within broccoli twin rows held to approximately 10% of adjacent weed biomass between the twin rows.

Broccoli Yield

Broccoli yield was unaffected by experimental treatments (data not shown), averaging 7 tons/acre (636 boxes/acre). There were no differences in quality (head size, texture, color, etc.) among treatments. These results further show that, when properly established and maintained, NT production systems are a viable option for producing broccoli (Hoyt et al., 1994). The SST-T used in this study is equipped with an in-row soil loosening (IRSL) device aligned ahead of the transplanter, which often improves stand establishment and crop yield (Morse et al., 1993).

In a recent review of 10 years of data (Morse, 1995), yields of cabbage and broccoli in IRSL/NT plots were increased by an average of 8% and 9%, compared to conventional tillage (CT) and unloosened NT plots, respectively. Compared to NT, yield stability was also enhanced during this 10-year period (1984-1994). Yields in IRSL/NT plots were generally equal to or higher than yields in unloosened NT plots. Only in an exceptional dry year (1991) was yields in IRSL/NT plots less than unloosened NT.

Summary and Conclusions

Based on data in this paper and presented elsewhere (Infante and Morse, 1995; Serage, 1993), no-till broccoli can be successfully produced without using contact or preemergent herbicides. In these studies, various cultural weed-control methods were combined to minimize interspecific (weed-broccoli) competition. Each cultural method either promoted rapid broccoli growth and/or reduced germination and growth of weeds.

(A). Heavy (dense, thick layer), uniformly distributed surface residues of soybean, buckwheat and foxtail millet were obtained prior to transplanting broccoli and maintained after transplanting. Rolling effectively killed mature annual cover crops, which persisted longer than mowed residues (Hoffman et al., 1993). Obtaining and maintaining (persistence) uniformly distributed, heavy surface residues is paramount for no-herbicide weed control, especially when the weed-seed population and soil environment are optimum for weed growth. Selecting rapid-growing, allelopathic cover crop species or mixtures of species for specific weed problems and using high-clearance, effective NT transplanters such as the SST-T (Morse et al., 1993) will help establish and maintain uniform, dense cover.

(B). Reduced weed-seed populations (stale seedbed) and relatively weed-free cover crops were achieved prior to transplanting. To be successful, NT fields should be free of weeds as possible at transplanting to aid the planted crop to secure a competitive advantage over subsequent germination and growth of weeds (Wicks et al., 1994). If established early, this controlled plant dominance hierachy (transplanted crop established first which dominates later germinating weeds) is generally relatively easy to maintain. Proper establishment of a dense, uniform cover crop will generate a stale seedbed by smothering germinating weeds. If the stale seedbed is left undisturbed at transplanting, weed growth will be minimized. If necessary, contact and/or preemergent herbicides applied at low rates before or shortly after seeding cover crops could be used. Appropriate use and timing of early pretransplant herbicides to achieve a stale seedbed and a dense weed-free cover crop is generally an inexpensive, more environmentally friendly use of herbicides than if applied later in conjunction with production of the transplanted crop.

(C). Canopy closure within the twin-row area (2 feet) occurred in approximately 5 weeks and virtually eliminated in-row weed growth. In all treatment plots, the fast-growing broccoli canopy outgrew weeds germinating between the broccoli twin rows in untreated plots (F and R), resulting in no broccoli yield reductions, compared with herbicide-treated plots (H/F and H/R). Narrow-row spacing (more equidistant plant populations) is known to increase the ability of row crops *to* compete with weeds (Forcella and Burnside, **1994).** Thus, the need for herbicides can be reduced or even eliminated when large, vigorous transplants are effectively set in narrow twin rows in persistent, heavy-residue NT systems.

Literature Cited

Dabney, S.M., and J.L. Griffeth. 1987. Efficiency of burndown herbicides on winter legume cover crops, p, 122-134. In J.F. Power (ed). Legume cover crops in conservation tillage production systems. Soil Cons. Soc. Amer., Ankeny, IA.

Dabney, S., M., N.W. Buehring, and D. B. Reginelli. 1991. Mechanical control of legume cover crops, p. 146-147. In W.L. Hargrove (ed). Cover crops for clean water. Soil and Water Cons. Soc., Ankeny, IA.

Forcella, F., and O.L. Burnside. 1994. Pest management—weeds, p. 157-197. In J.L. Hatfield, and D.L. Karlen (eds). Sustainable agriculture systems. Lewis Publ., Boca Raton, FL.

Hoffman, M.L., E.E. Reenier. and J. Cardina. 1993. Weed and corn *(Zea* Mays) responses to hairy vetch *(Viciavillosa)* cover crop. Weed Technol. 7:594-599.

Hoyt, G.D., D.W. Monks, and T.J. Monaco. 1994. Conservation tillage for vegetable production. HortTechnology 4(2):129-135.

Infante, M.L., and R.D. Morse. 1995. Integration of no-tillage and overseeded legume living mulches for transplanted broccoli production. HortScience (in press).

Morse, R.D. 1993. Components of sustainable production systems for vegetables—conserving soil moisture. HortTechnology 3(2):211-214.

Morse, R.D. 1995. In-row soil loosening improves plant survival and yield of no-till cabbage and broccoli. In K.J. Bradford and T.K. Hartz (eds). Proc. Fourth Nat. Symp. on Stand Establishment (April 23-26, 1993, Monterey, CA.

Morse, R.D., D.H. Vaughan, and L.W. Belcher. 1993. Evolution of conservation tillage systems for transplanted crops; potential role of the Subsurface Tiller Transplanter (SST-T), p. 145-151. *In* P.K. Bollich (ed). Proc. Southern Conservation Tillage Conference for Sustainable Agriculture, Monroe, LA.

Schlotzhauer, S.D., and R.C. Littell. 1987. SAS system for elementary statistical analysis. SAS Institute, Inc. Cary, ,NC.

Serage, T.I. 1993. Effects of overseeded legume living mulches and tillage on weed suppression and broccoli yield. MS Thesis, Virginia Polytech. Inst. and State Univ., Blacksburg, VA.

Standifer, L.C., and C.E. Beste. 1985. Weed control methods for vegetable production with limited tillage, p. 93-100. In A.F. Wiese *(ed).* Weed control in limited tillage systems. Weed Sci. Soc. Amer., Champaign, IL.

Swanton, C.J., and S.F. Weise. 1991. Integrated weed management: The rational and approach. Weed Technol. 5:657-663.

Virginia commercial vegetable production recommendations. 1994. VA Coop. Ext. Serv. Publ. 420-456.

Wicks, G.A., O.C. Burnside, and W.L. Felton. 1994. Weed control in conservation tillage systems, p. 211-244. In P.W. Unger (ed). Managing agricultural residues. Lewis Publ., Boca Raton, FL.

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