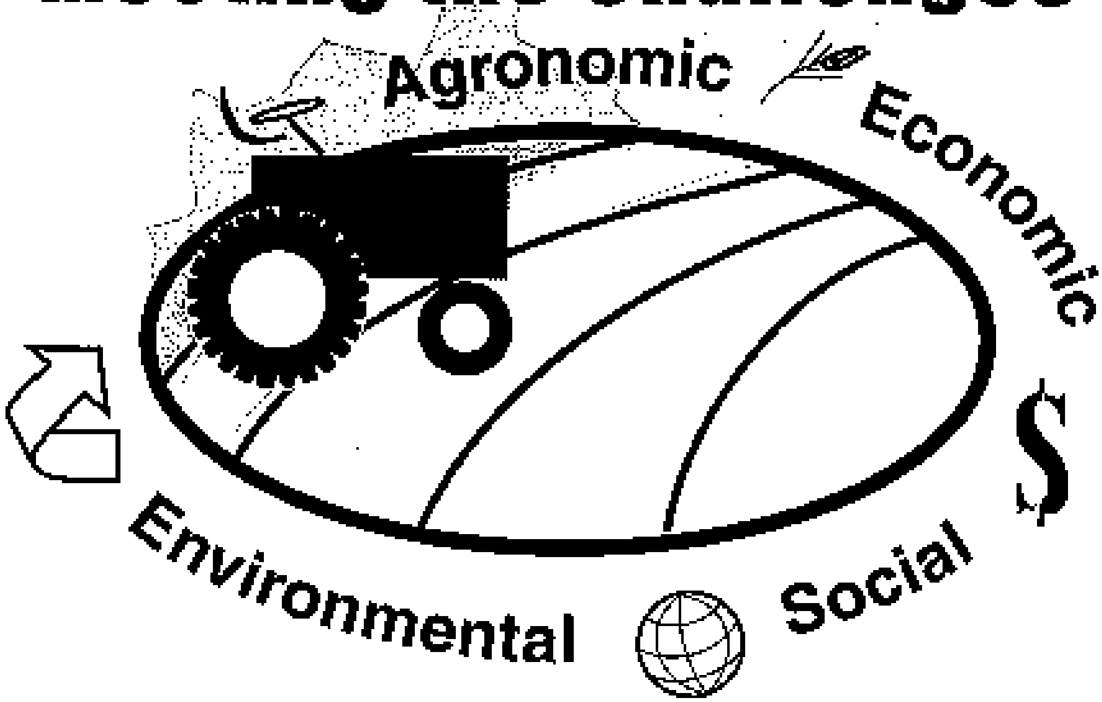
Meeting the Challenges



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Foreword

Conservation tillage, especially no-till, gained greater acceptance during the decades of the 1960s and 1970s. This acceptance coincided with the availability of herbicides that could substitute for mechanical cultivation for weed control. Highly erodible locations were usually the first to implement conservation practices.

Conservation tillage generally reduces erosion, conserves energy costs associated with tillage operations and modifies soil-water relationships. Conservation tillage often requires greater herbicide use to obtain acceptable weed control. Under reduced tillage scenarios, applied lime and fertilizer tend to concentrate in the surface few inches of soil. Greater capture of rainfall and fast transmission of water via large pores to greater depths may pose an increased potential for ground water contamination with pesticides and nitrates. In some cases, continual cropping without mechanical tillage has resulted in increased surface soil compaction.

Conservation tillage issues that evolved during the 1980s included effective herbicide and fertilizer use, proper soil sampling techniques, insect and disease management, crop residue management, soil-water relations, surface and ground water protection and profitability of crop production. Numerous production problems have been addressed, and various solutions are being tested. As conservation technology improves, its acceptance continues to increase.

During the 1990s, as much as 35% of the crop land in the United States is being farmed with some kind of conservation tillage practice. The advent of bioengineering of herbicide-resistant crops has made weed control in conservation tillage easier. With adaptation of conservation tillage, equipment that addresses various problems that occur when using conservation tillage has been developed in farm shops and then been offered commercially by equipment companies.

The 1998 conference theme, "MEETING THE CHALLENGES" was chosen for its focus on removing the barriers of further adaptation of conservation tillage while sustaining that which is in place. To be sustainable requires that a balance among profitable agriculture production, socially acceptable practices and environmentally sound practices be achieved. The 1998 conservation tillage conference continues to provide a communication link among various agencies and personnel interested in improved natural resource management. We here at the University of Arkansas appreciate the opportunity to host this annual conference and to facilitate the adaptation of conservation tillage technology.

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Contents

A COMPARISON OF TILLAGE SYSTEMS FOR WITHIN-FIELD VARIABILITY OF COTTON YIELD AND FIBER PROPERTIES

Philip J. Bauer, John A. DuRant and James R. Frederick[1]

ABSTRACT

There is considerable variability for lint yield within cotton (*Gossypium hirsutum* L.) fields in the southeastern Coastal Plain. The objective of this experiment was to determine if soil management techniques and in-furrow application of an insecticide/nematicide influence the amount of variability in cotton yield and fiber properties. Treatments in the study were tillage (conservation vs. conventional) and aldicarb application (1.07 lb ai/acre vs. none). In 1997, 'DPL Acala 90' was planted into large plots (ranging in length from approximately 400 to 800 ft, plots were six 38-in.-wide rows) that spanned across several soil map units. Two harvesting methods were used to determine variability. First, the large plots were subdivided into 44-ft-long sections, and two of the rows in each section were harvested with a spindle picker. Second, a 6-ft sample was hand-harvested from each of three soil map units (Bonneau sand, Eunola loamy sand and Norfolk loamy sand) within each plot. Neither aldicarb application nor tillage system affected the variability for yield or micronaire among the machine-harvested samples. Variability for fiber length was less in conservation tillage than in conventional tillage only when aldicarb was applied. For fiber strength, conservation tillage had lower variability than conventional tillage for the plots without aldicarb. Soil map unit was responsible for much of the variation in yield, with the Bonneau sand having lower yield than the other two soil map units. Variability for fiber properties was less than variability for yield.

INTRODUCTION

A large amount of variation in cotton growth and productivity can occur within the cotton fields of the southeastern Coastal Plain. One of the largest sources appears to be variation due to soil map unit. Fields in this region generally have many soil map units and a range of physical and chemical properties that influence crop growth (Karlen et al., 1990). The primary productivity differences among soil map units may be in differences in ability to supply water to crops. Sadler et al. (1998) found a significant relationship between canopy minus air temperature and soil map unit in corn (*Zea mays*) during a severe water deficit year, which implied that soil physical differences caused differences in water stress.

Many of the benefits of conservation tillage, especially when used with adequate residue cover, are related to improving soil water conditions. Benefits often cited include increased rainfall infiltration, reduced runoff and reduced evaporation from the soil surface. Thus, conservation tillage techniques may reduce the amount of field variability for cotton yield by reducing the amount of in-field variability for soil water.

Besides soil map unit, pest infestations are a source of variability in the southeastern Coastal Plain cotton fields. Although seldom random, infestations of weeds, insects and nematodes do not tend to be uniformly distributed throughout a field. Though pests are rarely uniformly distributed, pest control measures are usually applied uniformly throughout a field. Part of the reason for this is the uncertainty of where pest infestations will occur. Also, there is very little spatial data available on the efficacy of pest control products.

A six-year study was established in the fall of 1996 with the overall objective to determine the effects of residue amount, tillage system and in-furrow insecticide application on cotton yield and fiber properties. In this report, we describe our results from the first year of converting a field to a conservation tillage production system. The objective is to determine if soil management techniques and in-furrow application of an insecticide/nematicide influence the amount of variability in cotton yield and fiber properties.

MATERIALS AND METHODS

Seven acres of a 40-acre field at Clemson University's Pee Dee Research and Education Center near Florence, South Carolina, were used for the experiment. The area was chosen because of the diversity in soil map units and the ability to have at least two soil map units represented in each plot. Treatments were tillage (conventional or conservation) and in-furrow insecticide/nematicide application (aldicarb or none). Experimental design was split-plot with main plots in a randomized complete block. There were three blocks. Main plots were the tillage treatments, and subplots were the in-furrow insecticide application treatments. Main plot size was twelve 38-in.-wide rows that ranged in length from approximately 400 ft to more than 800 ft. Six of the rows received an in-furrow applica-

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tion of 1.07 lb ai/acre aldicarb, while the other six were planted without insecticide/nematicide protection to serve as controls.

In previous years, the field was in a two-year rotation of corn followed by winter wheat (*Triticum aestivum*) double-cropped with soybean (*Glycine max*). Corn was grown in the field during the summer of 1996. Following corn harvest, stalks were mowed. The experiment was originally designed to include a rye cover crop (both with and without tillage) treatment. Rye was planted 20 November 1996, but because of poor cover crop growth, these plots were pooled with the no-cover-crop main plots for this analysis. In the spring of 1997, paraquat was applied to the conservation tillage plots while the conventional tillage plots were disked and then smoothed with a harrow equipped with S-shaped tines and rolling baskets. On 2 May, a paratill with shanks spaced 26 in. apart was used to deep-till the entire experimental area to a depth of 16 in.

Cotton ('Deltapine Acala 90') was planted 7 May using a four-row planter equipped with waved coulters. Seeding rate was four seeds per row-ft. Preemergence herbicides (fluometuron and pendimethalin) were applied 8 May. Post-emergence herbicides included pyrithiobac, cyanazine and monosodium methanearsonate. All herbicides were applied at recommended rates. Plant nutrients (other than N) were broadcast applied before cotton planting at rates based on soil test results and Clemson University Cooperative Extension Service recommendations. All N was side-dress applied in a split application, with 40 lb N/acre being applied 13 May and 40 lb N/acre applied 20 June. All N applied was NH_4NO_3.

Two methods of harvest were used to assess the yield and fiber property variability. The first method involved separating each subplot into 50-ft-long sections and removing plants from 3 ft of row from each end of the sections so that the harvested area within each section was 44 ft long. A two-row spindle picker was used to harvest two of the rows in each section. A grab sample of seedcotton from each harvest bag was collected at harvest for fiber property determinations. The second method involved hand-harvesting 6 ft of row from individual soil map units within each plot. The map units chosen were Bonneau sand (BoB; loamy, siliceous, thermic Arenic Paleudult), Eunola loamy sand (EuB; Fine-loamy, siliceous, thermic Aquic Hapludult) and Norfolk loamy sand (NoA; fine-loamy, siliceous, thermic Typic Kandiudult). All three soil map units were present in all plots in two of the blocks. In the other block, the EuB soil map unit was in each main plot, while the BnA soil map unit was present in only one of the four main plots, and the NoA map unit was present in only three of the four main plots. All seedcotton samples were ginned on a 10-saw laboratory gin. Samples of the lint samples were sent to Star-Lab, Inc (Knoxville, Tennessee) for HVI fiber property determinations.

Bartlett's F test for homogeneity of variance was conducted to determine if the amount of variability differed between conventional tillage and conservation tillage for both levels of aldicarb application. Since the experimental design was split-plot with main plots in a randomized complete block design, variance components for each subplot treatment consisted of variation due to blocks and to within-plot variation. Therefore, an analysis of variance for treatment combination (tillage x aldicarb) was conducted to remove the variance component due to blocks, and the residual mean square was used as the estimate of σ^2 for conducting Bartlett's F test. For the hand-harvested samples, data were analyzed by analysis of variance using the general linear models (PROC GLM) procedure of SAS.

RESULTS AND DISCUSSION

Estimates of variance and Bartlett's F test for heterogeneity of variance among the machine-picked samples for lint yield, fiber length, strength and micronaire are given in Table 1. The amount of variability for cotton yield did not differ between conventional tillage and conservation tillage either with or without aldicarb application (Table 1). Similarly, variability did not differ for micronaire between the tillage systems either with or without aldicarb. Heterogeneity of variance was found for both fiber length and fiber strength. In both cases, the conservation tillage had lower variance than did conventional tillage. For fiber length, variance was lower for conservation tillage than for conventional tillage when aldicarb was applied (Table 1). For fiber strength, variance of the conservation tillage was less when aldicarb was not applied.

For the machine-harvest sampling method, a significant ($P < 0.10$) tillage x aldicarb interaction occurred for lint yield (Table 2). With aldicarb, the conventional and conservation tillage production systems had similar yield (Table 2), averaging 859 lb lint/acre. The interaction was caused by magnitude differences between aldicarb-treated and untreated cotton within each tillage system. In conservation tillage, yields of cotton without aldicarb were only 131 lb/acre less than the cotton treated with aldicarb. In conventional tillage, the difference between aldicarb-treated and untreated was 212 lb lint/acre (Table 2). Early-season counts indicated that thrips populations were less in the conservation tillage than in the conventional (data not shown). Only small, and probably inconsequential, mean differences among treatments occurred for fiber properties with the machine harvest sampling method. As expected, it appears that much of the within-plot variability found with the machine-harvest method was due to soil map unit.

Yield and fiber properties from the hand-harvested samples are given in Table 3. Averaged over tillage systems and aldicarb levels, lint yields were 694 lb/acre for the Bonneau, 913 lb/acre for the Eunola and 1020 lb/acre for the Norfolk. The average yield increase due to aldicarb was 158 lb lint/acre. The micronaire response was similar to yield, with lower micronaire occurring on the Bonneau soil map unit than on the other two and aldicarb-treated cotton having higher micronaire than untreated. As for the machine-harvested samples, variability for fiber length and strength was small, even when treatment means were significantly different. Notably, the cotton produced with conservation tillage on the Bonneau soil grown without aldicarb was substantially lower for yield and fiber quality than the other treatment combinations in the experiment.

Although the tillage x aldicarb x soil map unit interaction was not significant for lint yield (P = 0.198), inspection of the means provides some indication of why the tillage x aldicarb interaction occurred for yield with the machine-picked data. As discussed earlier, yield reductions without aldicarb were less in the conservation tillage production system than in the conventional tillage system. Aldicarb did not increase yield for the Eunola and Norfolk soils in the conservation tillage system but resulted in a substantial yield increase on these two soils in conventional tillage (Table 3). For the Bonneau soil, aldicarb treatment increased yield in both the conservation and conventional tillage treatments. Unfortunately, insect pest monitoring was not conducted on an individual soil map unit basis in 1997.

These preliminary data suggest that there can be substantial yield and fiber property variation within fields for cotton in the southeastern Coastal Plain. Additionally, although within-field variation for yield was not reduced with conservation tillage, conservation tillage did decrease the within-plot variation for fiber length and strength. Application of aldicarb did not reduce within-plot variability, nor did it have much of an effect on variability among soil types. More in-depth monitoring of insect and nematode pests is planned.

ACKNOWLEDGMENT AND DISCLAIMER

We thank Bobby Fisher, Van Atkinson and Gene Taylor for technical assistance and Ellen Whitesides for helping prepare the manuscript. Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA or Clemson University and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

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Table 1. Estimates of variance for yield and selected fiber properties of each tillage x aldicarb combination in the experiment and Bartlett's F test for homogeneity of variance. Estimates are for the machine-harvested samples.

			Estimate of σ^2			
Tillage	Aldicarb	n	Yield	Length	Strength	Micronaire
Conservation	Yes	54	25112	0.00050	0.9222	0.0767
	No	54	20665	0.00052	0.9820	0.0629
Conventional	Yes	58	21976	0.00086	1.3951	0.0688
	No	58	25963	0.00054	1.7355	0.0712
Bartlett's F-test Values for Homogeneity of Variance between Tillage Systems						
	Yes		1.14	1.72*	1.51	1.11
	No		1.26	1.04	1.77*	1.13

*Indicates F value significant at P = 0.05 (F values for determination of significance were estimated from F table values of $F_{0.05\ 40,40}$ = 1.69 and $F_{0.05\ 60,60}$ =1.53 [Steel and Torrie, 1980]).

Table 2. Average cotton yield and selected fiber properties as affected by tillage and aldicarb application. Data are from machine-picked samples.

Tillage	Aldicarb	Yield	Fiber Length	Fiber Strength	Micronaire
		lb lint/acre	in.	g/tex	units
Conservation	Yes	849	1.12	30.0	4.1
	No	718	1.11	30.3	4.1
Conventional	Yes	868	1.12	30.3	4.2
	No	656	1.11	30.4	4.1
Significance Level (Prob > F Value) From Analysis of Variance					
Tillage		0.788	***	***	0.469
Aldicarb		<0.001	***	***	0.213
Tillage x Aldicarb		0.066	***	***	0.859

*** Hypothesis testing for these variables is invalid because of heterogeniety of variance.

Table 3. Average cotton yield and selected fiber properties as affected by tillage, aldicarb application and soil map unit. Data are from hand-harvested samples.

Tillage	Aldicarb	Soil Map Unit	Yield	Fiber Length	Fiber Strength	Micronaire
			lb lint/acre	in.	g/tex	units
Conservation	Yes	Bonneau	795	1.09	32.6	3.7
		Eunola	912	1.11	32.4	4.0
		Norfolk	1056	1.12	32.7	4.1
	No	Bonneau	527	1.07	29.9	3.2
		Eunola	908	1.11	32.6	4.2
		Norfolk	1030	1.11	32.2	3.8
Conventional	Yes	Bonneau	785	1.12	33.8	3.7
		Eunola	1085	1.12	32.5	4.1
		Norfolk	1110	1.13	32.8	4.2
	No	Bonneau	658	1.10	32.5	3.7
		Eunola	749	1.11	32.3	3.9
		Norfolk	880	1.09	31.7	3.8
Significance Level (Prob > F Value) From Analysis of Variance						
Tillage			0.704	0.295	0.127	0.259
Aldicarb			0.007	0.031	<0.001	0.049
Soil			<0.001	0.482	0.775	0.003
Tillage x Aldicarb			0.273	0.622	0.787	0.890
Tillage x Soil			0.736	0.066	0.002	0.460
Aldicarb x Soil			0.929	0.627	0.012	0.241
Tillage x Aldicarb X Soil			0.198	0.357	0.208	0.205

SOIL STRENGTH IN RYE AND FALLOW WINTER COVER IN THE SOUTHEASTERN COASTAL PLAIN

W.J. Busscher and P.J. Bauer[1]

ABSTRACT

On sandy coastal subsurface hardpan soils, cover crops have the potential to prevent erosion and scavenge nutrients. Our objective was to determine the effect of cover crops and tillage on soil strength and cotton yield. Treatments were surface tillage (disked or none), deep tillage (in-row subsoiled or none) and cover crop (rye or fallow). Soil strength (cone index) differences were measured for tillage treatments (deep tilled < none), depth (higher strength in the pan) and position across the row (in row < non-wheel track < wheel track). Lower cone indices were found in the non-tilled rye cover, suggesting that the cover helped maintain low strengths. Higher cone indices in the disked treatments suggested that the disking aided recompaction.

INTRODUCTION

In the southeastern Coastal Plains, winter cover is important for long-term conservation tillage crop production. Cool- and warm-season annual double crops are needed for successful conservation tillage production of grain sorghum [*Sorghum bicolor* (L.) Moench] and soybean [*Glycine max* (L.) Merrill] on southeastern Piedmont sandy loams (Langdale et al., 1990). However, because of the long southeastern cotton growing season, double cropping with continuous cotton is not possible for much of the region. In addition, low organic matter produced by cotton can leave a field bare for the winter.

Cover crops provide winter cover to improve erosion control and increase infiltration. They can also scavenge nutrients and reduce groundwater pollution. Cover crops might also provide the beneficial rotational effect of double crops seen by Langdale et al. (1990).

Because of the subsurface root-restricting E horizon of many Coastal Plain soils, in-row subsoiling is needed to help roots penetrate into the clay-textured B horizon. In-row subsoiling provides a narrow, soft zone below the row that roots can use to penetrate through the E and grow into the B horizon. By adding organic matter from both roots and cover, cover crops may also help maintain lower soil strength.

Our objective was to determine the influence of surface tillage, deep tillage and a rye cover crop on soil strength and cotton lint yield.

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MATERIALS AND METHODS

In 1990, we established cover crop plots at the Clemson University Pee Dee Research and Education Center near Florence, South Carolina. Bauer and Busscher (1993) reported the results from the 1991 and 1992 experiment. In 1993, cotton was grown on the plots but not harvested because of a drought. All plots were subsoiled in spring 1993.

In 1994 and 1995, we changed the treatments to subsoiling only half the plots. During these two years, experimental treatments were winter cover (rye and fallow), surface tillage (disking and none) and deep tillage (in-row subsoiling and none). The experimental design was split-split plot randomized complete block. Main plots were winter cover, subplots were surface tillage, and subsubplots were deep tillage. Subsubplots were 12.7 ft wide (four 38-in. rows) by 50 ft long. The experiment had four replicates. The soil was a Norfolk sandy loam (fine, loamy, siliceous, thermic, Typic Kandiudult).

In October 1993 and 1994, after the cotton stalks were shredded, half the plots were seeded with rye cover (110 lb of seed/acre). Plots were seeded in 7.5-in. rows using a John Deere 750 grain drill.

In a separate operation immediately prior to planting, half the subsubplots were subsoiled using a KMC four-row subsoiler within 6 in. of the previous year's rows. In mid-May, cotton ('DES 119') was seeded within 6 in. of the previous year's rows with a four-row Case-IH 900 series planter equipped with Yetter wavy coulters. We attempted to maintain the same wheel tracks and rows from year to year. However, because the old rows were no longer visible, locating wheel tracks was more difficult in the disked than in the non-disked plots

Nitrogen (80 lb N/acre as ammonium nitrate) was applied in a split application, half at planting and half one month after planting. For each application, N was banded approximately 4 in. deep and 6 in. from the rows. Lime, P, K, S, B and Mn were applied based on soil test results and Clemson University Extension recommendations. Weeds were controlled with a combination of herbicides, cultivation (disked plots only) and hand-weeding. Insects were controlled by applying aldicarb (0.75 lb ai/acre) in-furrow. Other insecticides were applied as needed.

Soil strength was measured in early June with a 0.5-in.-diameter, 30^{o} solid angle cone tip, hand-operated, recording penetrometer (Carter, 1967). Strength measurements were recorded to a depth of 24 in. at nine positions across a mid-plot row (from non-traffic midrow to traffic midrow). Each measurement was the mean of three probings from each subsubplot. Data were recorded on index cards and digitized into the computer using the method described by Busscher et al. (1986). Data were log transformed before analysis for normalization (Cassel and Nelson, 1979).

Along with the cone indices, water contents were measured at 4-in. depth increments in the non-wheel-track midrow and in the row. These selected water contents were considered representative of the water contents for each subsubplot.

In mid to late October, cotton was chemically defoliated. In early November, seed cotton yield was measured by harvesting two interior rows with a two-row spindle picker. Each harvest bag was subsampled, and the subsample was saw-ginned to measure lint percent. Seed cotton yield was multiplied by lint percent to estimate lint yield.

Data were analyzed using ANOVA and the LSD mean separation procedure (SAS Institute Inc., 1990). Unless otherwise specified, differences were significant at P = 0.05.

RESULTS AND DISCUSSION

In late summer 1994, hail ruined part of the field that included half of replicate one. After this, the replicate was ignored and the other three were used for analysis.

Depth

For both years and over all tillage treatments, cone index differed with depth (Table 1 and Fig. 1). The highest cone indices were found at the 12- to 16-in. depths, the bottom of the E horizon. This high subsoil strength was the main reason for implementing the deep tillage.

Some cone index differences with depth were caused by water content changes (Table 1). For example, the softer soil below the hard layer (> 16 in.) was also wetter. At this depth, soil type generally changed from loamy sand to sandy clay loam. The sandy clay loam held more water and had structure. The higher water content reduced cone index and provided nourishment for the root, if it could penetrate the pan above. The structural faces provided zones of weakness along which roots could grow, even if the soil dried and hardened.

Position

Cone index varied with position across the row (Table 2 and Fig. 1). These differences distinguished lower strength under the non-wheel-track midrow (Fig. 1, position = 0 in.) than the wheel-track midrow (position = 38 in.). The lowest cone indices were found in the midrows (position = 19 in.) because of this year's deep tillage or residual effects from past deep tillage in the non-deep-tilled treatments.

Tillage

Mean profile cone indices (M) did not differ between disked and non-disked treatments. An exception to this was the 1994 non-deep-tilled treatments where disked treatments had lower M (Table 3). This was a result of lower cone indices in the surface 4 in., caused by the disking. This zone of lower strength was apparent in the other cases (Fig. 1) but not significantly different.

As expected, M for the deep-tilled treatment was lower than for the non-deep-tilled treatment (Table 3). An exception to this was the disked treatment in 1994 where M's were about the same for both deep tilled and non-deep-tilled treatments. The similarity of the M's could be explained partly by the residual effects of 1993 subsoiling in the non-deep-tilled treatment, giving this profile a loosening pattern similar to the deep-tilled treatment (Fig. 1). Also, since both treatments were disked, the upper parts of both profiles were loosened.

Cover

Most strength interactions with cover were accompanied by water content differences. The higher strengths had lower water contents. Most of these differences were in the lower half of the measured profile.

In the non-disked treatments, the rye cover treatment had lower cone indices (and higher water content) than the fallow treatment (Table 4). This would be consistent with better infiltration usually associated with treatments that have better cover.

The opposite was seen in the disked treatments, where the fallow treatment had the lower cone indices (and higher water contents). This would be consistent with root uptake by the rye.

In 1994, cotton yield was higher for fallow cover in the non-disked treatments and for rye cover in the disked treatments (Table 4). This was a result of the large amount of cover in the 1994 rye cover treatments that made planting difficult in the non-disked rye cover and added a significant amount of organic matter to the disked treatment (Bauer et al. 1995).

In 1995, in the non-subsoiled treatments, cone indices were lower for the non-disked rye than fallow and higher for the disked rye than fallow (Table 4). Lower cone indices for the non-disked rye suggested that the cover (and the roots from the cover crop growing within the profile) helped maintain low strengths, even for soils with hardpans at 12- to 16-in. depth. Higher strengths for the disked rye suggest that disking can eliminate these reductions in strength. Since the profile as a whole was higher in strength and since disking loosened the upper part of the profile (as seen above), the lower part of the profile, the pan, would have had to be compacted. Lower cone indices suggest higher yields for the non-disked treatment. Higher yields were found, although they were not significantly different. Also not significantly different, the 1994 cone index data showed the same trend as the non-subsoiled 1995 cone index data. Water contents for these treatments were not significantly different.

Cover crops have a number of known advantages: reducing erosion, reducing leaching of nutrients and increasing organic matter. It is also advantageous to know that they can be used without reducing cotton yield (and perhaps increasing it) by helping maintain low soil strength.

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We thank E.E. Strickland and B.J. Fisher for technical support. Mention of trademark, proprietary product or vendor does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

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Table 1. Cone indices and water contents by depth.

Depth (in.)	Cone Index (Atm) 1994	Cone Index (Atm) 1995	Water Content (lb/100 lb) 1994	Water Content (lb/100 lb) 1995
2	10.3f*	8.9f	5.8e	10.6c
6	21.7e	18.6e	6.0de	10.0d
10	36.1d	24.5d	6.8c	10.0d
14	57.1a	38.5a	6.6cd	10.2cd
18	46.0b	30.3c	8.3b	11.6b
22	41.6c	31.3b	10.3a	12.9a

* Means by year with the same letter are not different (LSD at 5%).

Table 2. Cone indices by position across the row.

Position	Cone Index (Atm) 1994	Cone Index (Atm) 1995
Non-wheel track	24.3b	19.6b
In row	19.7c	11.9c
Wheel track	31.2a	22.3a

* Means by year with the same letter are not different (LSD at 5%).

Table 3. Mean profile cone index by tillage treatment.

Tillage Surface	Tillage Deep	Cone Index (Atm) 1994	Cone Index (Atm) 1995
Non-disked	Non-subsoiled	27.4a	21.4a
Non-disked	Subsoiled	23.1b	17.5b
Disked	Non-subsoiled	23.3b	20.7a
Disked	Subsoiled	22.6b	17.5b

* Means by year with the same letter are not different (LSD at 5%).

Table 4. Mean profile cone index and yield by deep tillage, surface tillage and cover.

Surface Tillage	Deep Tillage	Cover	Cone Index (Atm) 1994	Cone Index (Atm) 1995	Yield (lb/acre) 1994	Yield (lb/acre) 1995
Disked	Subsoiled	Fallow	21.2	16.1b	1060	665
		Rye	24.0	16.8b	1200	724
	Non-subsoiled	Fallow	22.3	18.3b	1110	695
		Rye	24.3	21.2a	1210	619
Non-disked	Subsoiled	Fallow	23.4	16.9b	1299	567
		Rye	22.8	16.2b	1010	724
	Non-subsoiled	Fallow	29.0	21.2a	1240	624
		Rye	25.9	19.6b	1000	838

* Means by year with the same letter are not different (LSD at 8%).

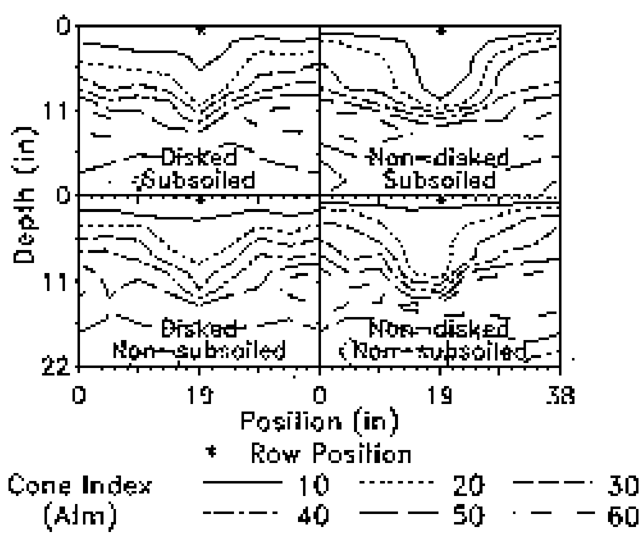

Fig. 1. Isostrength lines for treatment profiles in spring 1994 averaged over covers.

CULTURAL AND CHEMICAL REDVINE (*BRUNNICHIA OVATA*) CONTROL IN SOYBEAN

T.A. Castillo, T.K. Keisling and L.R. Oliver[1]

ABSTRACT

A long-term field study was initiated in 1996 to evaluate tillage methods and herbicide treatments for redvine control in soybeans (*Glycine max*). Aerial photography and Global Positioning System (GPS)/ Global Information Systems (GIS) were used to monitor redvine movement. At trial initiation, redvine populations averaged 15 to 25 per m^2 and resulted in 42 to 50% groundcover. A split plot design was used with tillage type as the main plot and herbicide treatment as the subplot. Tillage types included no-till, conventional, hyperbolic subsoiler and moldboard plow. Subsoiling and plowing operations were conducted in the fall of 1996. Herbicide treatments included no herbicide, glyphosate at 1.1 kg ai/ ha (1.0 lb ai/acre) applied annually to V2 and V6 soybeans and dicamba at 2.2 kg ai/h (2.0 lb ai/acre) applied 2 weeks prior to 1996 soybean harvest. When a herbicide was not used, moldboard plowing was the only tillage type that provided acceptable season-long control (83%). The subsoiler provided 50% control of redvine, but by harvest regrowth had occurred, resulting in only 24% control. Stem counts were reduced by moldboard plowing and subsoiling. Conventional tillage actually increased stem counts. Glyphosate increased control of redvine for all tillage treatments except moldboard plowing. Glyphosate at V2 and repeated at V6 provided redvine control for one month after the V6 treatment; however, late-season regrowth resulted in only 54 to 66 % control at harvest. Dicamba provided 96% control regardless of tillage type. Redvine density did not affect soybean yield in 1997.

INTRODUCTION

As reduced tillage systems become more popular, redvine and other perennial weeds are becoming an increasing problem in the Mississippi Delta (Elmore, 1984). Redvine has an extensive underground stem and root system, capable of vegetative propagation (DeFelice and Oliver, 1980). Control of this weed requires that a substantial concentration of herbicide reach the root system (Shaw and Mack, 1991). If applied during the fall, when the redvine plants are translocating sugars to their root structures, dicamba can reduce groundcover levels for at least two years (Elkins et al., 1996). Disruption of the root structure by deep tillage has also been found to reduce redvine groundcover levels (Elkins et al., 1996). Tillage operations may also contribute to the spread of perennial weeds throughout a field (Soteres and Murray, 1982). The objective of this study was to further develop redvine control programs in Roundup Ready soybeans with tillage methods and systemic herbicides and to monitor the regrowth and movement of redvine within the treatment.

MATERIALS AND METHODS

A 10-ha farmer-cooperator field near Keiser, Arkansas, containing a high natural population of redvine was selected for study. A split plot design with four replications was used. The main plots consisted of four tillage methods: no-till, conventional tillage, hyperbolic subsoiler and moldboard plow. Subsoiling and moldboard plowing operations were conducted upon initiation of the experiment in the fall of 1996. Subplots were herbicide treatments and included dicamba applied two weeks prior to harvest in 1996 at 2.2 kg ai/ha, glyphosate applied annually to V2 and V6 soybeans at 1.1 kg ai/ha and an untreated check. 'Asgrow 4701RR' soybean cultivar was drill seeded to the 15- x 15-m plots 13 May 1997. Visual control ratings were taken at planting, one, two and three months after planting and at harvest. Redvine stem counts/m^2 were also taken from the same plot area each year prior to harvest. The entire plot area was harvested for soybean yield. Original plot locations were mapped with Global Positioning Systems (GPS) technology, and aerial photographs are being taken semiannually to monitor the location and movement of redvine with the use of Geographic Information Systems (GIS) software. All data were subjected to analysis of variance, with means separated by Fishers Least Significant Difference (LSD) at the 0.05 significance level.

RESULTS AND DISCUSSION

Tillage Alone

When no herbicide was used for redvine control, moldboard plowing was the only tillage treatment that provided acceptable control for the entire growing season (Fig. 1). When the top portion of the soil profile was turned, subterranean redvine parts were sliced off 20 cm below the soil surface. Regrowth from the remaining taproot was hindered and may have required the formation of new buds from root tissue. Fragmented stem segments were deposited at the soil surface. Exposure to cold and wet condi-

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tions during the winter of 1996-1997 desiccated these fragments and prevented regeneration. Both factors led to an 83% reduction in stem counts (Table 1). Control with the hyperbolic subsoiler was much less. The subsoiler disturbed less than half of the soil matrix, leaving many established roots and rhizomes intact for regrowth. At harvest, control with the subsoiler was similar to that with conventional tillage but higher than the no-till check (Fig. 1). Only the conventional-tillage method increased stem counts (Table 1).

Tillage + Glyphosate

Sequential applications of glyphosate increased redvine control over that of tillage alone, except for moldboard plowing (Fig. 2). Glyphosate provided control for one month after treatment; however, late summer regrowth caused final ratings to decline, resulting in 54 to 66% control for all tillage types. Glyphosate reduced stem counts only in the conventional tillage plots (Table 1).

Tillage + Dicamba

Regardless of tillage type, dicamba provided excellent control for the entire year (Fig. 3). Only minimal regrowth occurred late in the season.

Soybean Yield

Redvine density did not affect yield. While the presence of redvine may alter the microclimate through competition for light and soil moisture, the less-than-complete plot coverage and narrow-row soybeans compensated for the interference. Although redvine may not directly affect returns, the long vines often entangle machinery, causing substantial tillage and harvest complications.

CONCLUSIONS

Acceptable redvine control requires that the underground portion of the plant be killed by either moldboard plowing or the use of dicamba. Split applications of glyphosate can keep redvine at a manageable level below the crop canopy. Subsoiling provided early-season control, but stem counts at harvest were not reduced over no-till. Conventional tillage may actually increase redvine populations and areas of infestation. Redvine did not affect soybean yields.

ACKNOWLEDGMENTS

The authors would like to thank the Arkansas Soybean Promotion Board for funding this project and the Jimmy Flecher Farm for providing the test area.

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Table 1. Reduction in redvine stems/m² 1996-1997.

	Herbicide program		
Tillage Level	Untreated	Glyphosate*	Dicamba**
	----------------------	%	---------------------
No-till	11	21	**96**
Conventional	-25	19	**99**
Subsoiler	38	46	**100**
Moldboard	**83**	72	**100**
LSD (0.05%) = 22			

*Glyphosate at 1.1 kg ai/ha applied V2 and V6
**Dicamba at 2.2 kg ai/ha applied preharvest 1996.

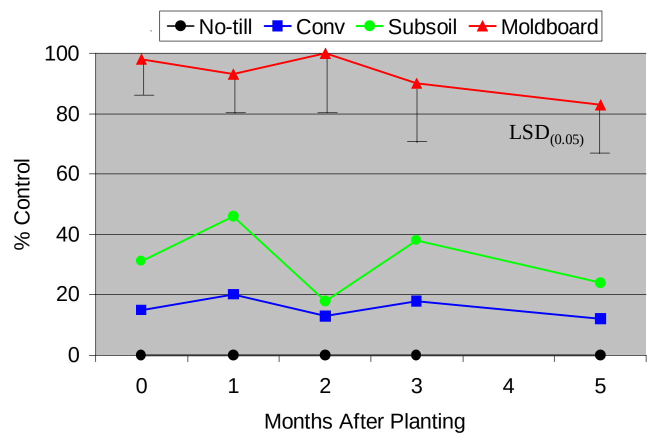

Fig. 1. Redvine control with tillage alone (no herbicide), 1997.

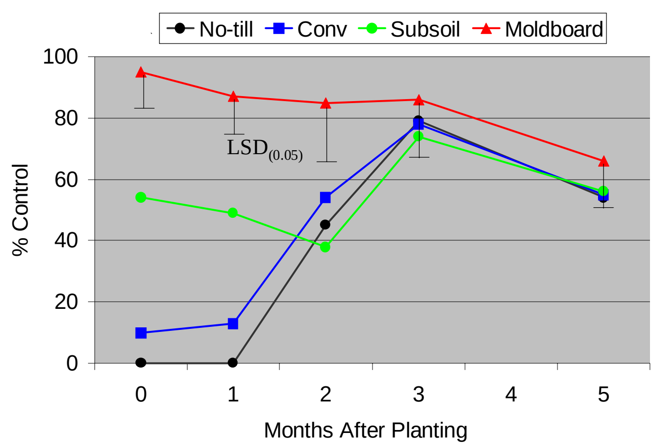

Fig. 2. Redvine control with tillage and glyphosate (1.1 kg ai/ha) applied to V2 and V6 soybeans (1 and 2 months after planting in 1997).

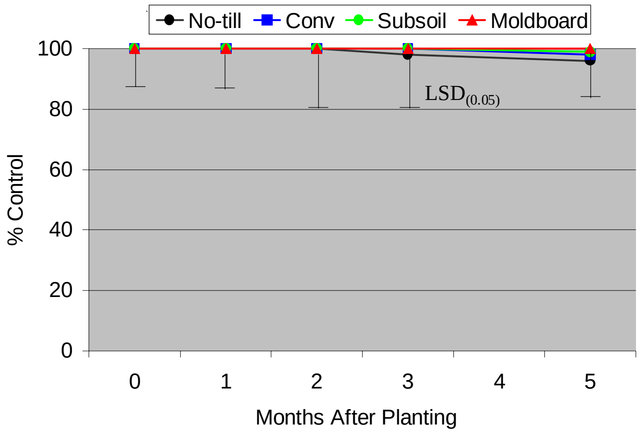

Fig. 3. Redvine control with tillage and dicamba (2.2 kg ai/ha) applied in fall 1996.

USING GRID SOIL SAMPLING IN THE MANAGEMENT OF PROBLEM SOILS[1]

M.B. Daniels, S.L. Chapman, R. Matlock and A. Winfrey

RESEARCH PROBLEMS

Underlying soil fertility problems such as high sodium levels, excess soluble salts and micronutrient imbalances can limit plant response to nitrogen, phosphorus and potassium fertilizers and lime even when soil test recommendations warrant such additions. Management options for these soils are sometimes limited due to practical and economic constraints. The objective of this study was to determine if the use of precision agricultural technology could provide information that would increase fertility management options on problem soils.

BACKGROUND INFORMATION

Grid soil sampling is primarily being used as a basis for variable rate application of fertilizers and lime. Regardless of variable rate fertilizer technology, grid soil sampling may be an important management tool. It provides information at a level of detail that may be necessary for other purposes, such as setting realistic yield goals, explaining yield variability and trouble shooting problem soils.

Plant response can vary within a field with problem soils ranging from seedling death in some locations to normal growth and yield at other locations. This variability can make it difficult to diagnose and remedy the problem with normal composite soil sampling from good and bad areas. Intensive soil sampling may provide information so that the problem can be adequately identified and the spatial extent of the problem adequately delineated. Ultimately, this increased knowledge may lead to increased management strategies for problem soils.

RESEARCH DESCRIPTION

The study was conducted in the spring of 1997 in southwestern Hot Spring County in a 70-acre production field. Historically, soybean yields in parts of this field have been severely limited due to excess soluble salts. Within this field, the soils are mapped as Adaton, Gurdon and Sardis silt loams. The Gurdon series is closely related in texture and landscape position to the Foley silt loam, which is characterized by a natric (high sodium content) horizon.

In order to determine the distribution of soluble salts and sodium within the field, soil samples were obtained on approximately a 2.5-acre grid while the field was fallow. The grid points were somewhat irregular (Fig. 1) and more dense where there was visual evidence of salt problems (lack of vegetation) to ensure that problems areas smaller than 2.5 acres were not excluded from the sampling. At each grid point, samples were collected with an NRCS probe truck using a 3-in.-diameter collection tube. Samples were taken from four depths down to 24 in. in 6-in. increments. The samples were shipped to the University of Arkansas Soil Test Lab at Marianna for routine soil analysis.

The latitude and longitude coordinates were determined for each grid point with a hand-held DGPS (Post Processing). Coordinates for the perimeter of the field were also recorded. Soil nutrient maps were constructed using SSToolbox GIS software (SST Development Group, Inc.). Soil test point data was converted to surface data using kriging procedures.

RESULTS

Soil test results indicated low fertility levels of P, K and pH (Table 1). Field averages of electrical conductivity (EC) and sodium did not indicate excessive levels of soluble salts or sodium at any depth interval. However, sodium levels at all depth intervals were highly variable ranging from 100 lb/acre to greater than 999 lb/acre (Maximum value reported by lab) with coefficients of variation, ranging from 62 to 80%. For a silt loam texture, it is thought that sodium values exceeding 500 lb/acre would adversely impact crop growth. The number of acres exceeding this threshold value increased from 6 acres in the top 12 in. to 7 acres at the 12- to 18-in. depth interval to 24 acres at the 18- to 24-in. depth interval (Fig. 1 and 2).

Because the farmer was considering land leveling this field, elevation data (locations recorded with DGPS) relative to a benchmark datum was obtained from Bowls Surveying (Fig. 3). Overlaying procedures using GIS software were performed on the maps in Fig. 2 and 3 to determine if land leveling would expose more acreage exceeding the 500-lb/acre sodium threshold (Fig. 4). From this analysis, it was determined that potentially 4 more acres of sodium exceeding the threshold might occur in the top 12 in. if land leveling was performed.

[1]Published in Arkansas Soil Fertility Studies 1997, Wayne E. Sabbe, editor. Arkansas Agricultural Experiment Station Research Series 459:24-28.

PRACTICAL APPLICATION

The results obtained from this study have been used to help make crucial management decisions related to this field. From Fig. 1, it was determined that 8% of the field could suffer crop damage from salt. From Fig. 2, 3 and 4, it was determined that land leveling could potentially increase the sodium hazard in the top 12 in. of the root zone by 4 acres up to a total of 13% of the acreage. The farmer proceeded with land leveling because he felt the advantage of better water management outweighed the small increase (5%) in sodium hazard.

By knowing the sodium distribution, the producer was able to prioritize his management options. Instead of focusing his attention on the 8% of the field affected by sodium, he can address the low fertility problems in the other 92% of the field where pH, P and K are limiting crop production. Before, it was assumed that poor crop production from the field as a whole was a result of high salt levels rather than poor fertility.

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Table 1. Selected soil test results by depth.

Depth		ph	P	K	Na	EC
In.			--------lb/acre--------			µmhos/cm
0-6	Mean	4.7	11	67	320	190
	s.d. (+/-)	0.3	4	13	253	265
	Minimum	3.9	10	50	100	35
	Maximum	5.6	29	105	999	1366
6-12	Mean	4.8	11	52	328	128
	s.d. (+/-)	0.5	4	8	220	140
	Minimum	3.9	10	50	113	24
	Maximum	6.8	34	105	999	620
12-18	Mean	4.7	11	53	350	134
	s.d. (+/-)	0.4	2	12	219	141
	Minimum	3.9	10	50	143	24
	Maximum	6.8	19	129	999	620
18-24	Mean	4.6	10	57	418	153
	s.d. (+/-)	0.3	---	15	269	148
	Minimum	4.0	---	50	136	31
	Maximum	6.2	---	148	999	682

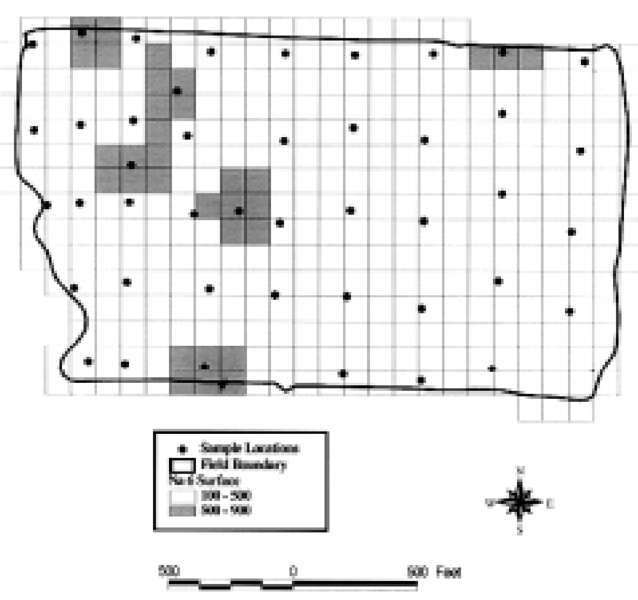

Fig. 1. Map of field boundary, soil sample location and sodium (lb/acre) distribution in the top 6 in. Grid cells represent 10,000 ft^2 (~0.25 acres).

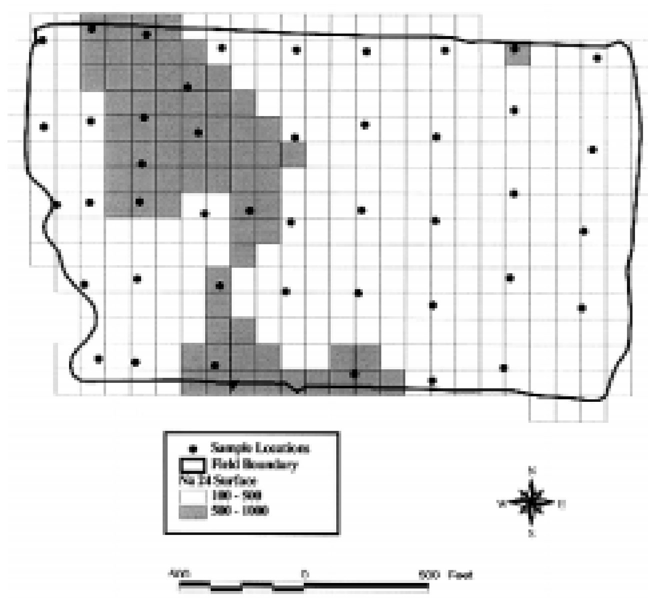

Fig. 2. Map of sodium (lb/acre) distribution at 18 to 24 in. Each grid cell represents 10,000 ft^2 (~0.25 acres).

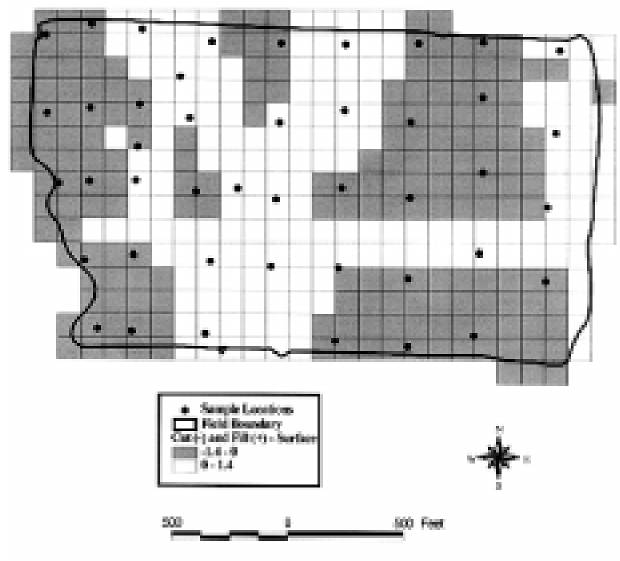

Fig. 3. Map of cut sheet used for land leveling. Positive values refer to areas of fill (ft) while negative values refer to areas of removal (ft). Data furnished by Bowls Surveying, England, Arkansas.

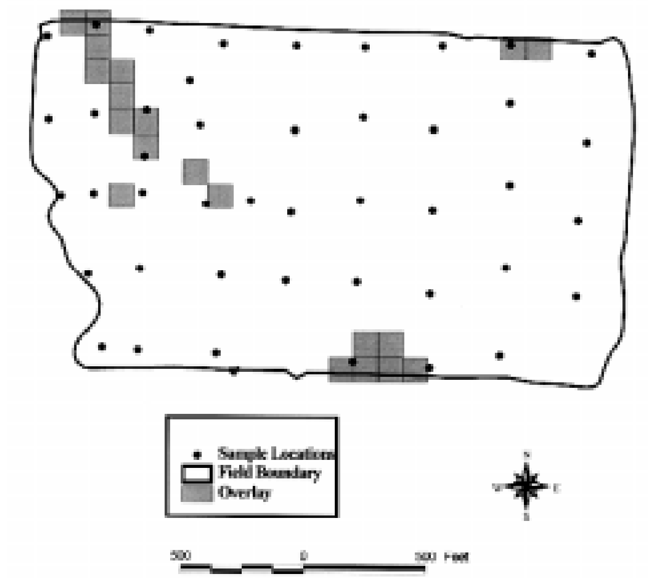

Fig. 4. Map of intersection between cut areas and sodium distribution (>500 lb/acre) at 18 to 24 in. Map created by using overlay techniques on Fig. 2 and 3.

VESICULAR ARBUSCULAR MYCORRHIZAE (VAM) IN NO-TILLAGE COTTON

Ernest H. Flint, Jr., Glover B. Triplett, Jr., Seth M. Dabney,
William H. Batson, Dawn S. Luthe and Clarence E. Watson[1]

INTRODUCTION

Performance of no-tillage cotton (*Gossypium hirsutum* L.) in the mid-South has ranged from yield decreases (Brown et al., 1985; Stevens et al., 1992) to yield increases (Bradley, 1995; Triplett et al., 1996). Both the Brown et al. (1985) and Stevens et al. (1992) studies were conducted for three years with no-tillage yields improving as studies progressed. Triplett et al. (1996) reported reduced no-tillage yields for the first year of their study with improved productivity as time progressed so that no-tillage yields were greater than conventional during years three through five. Thus, a period of time may be required for cotton yields to reach their full potential following implementation of no-tillage practices. Site characteristics may be a factor, as well, in performance of different systems as all studies cited were located on coarse ormedium textured soils.

In the non-irrigated study reported by Triplett et al. (1996), percentage yield improvement with no-tillage was greatest during moderately dry years. This implies that no-tillage improved moisture relations in some manner. Increased moisture for the crop could have resulted from increased rainfall infiltration through established macropores, slower runoff due to mulch, reduced evaporation under mulch, some factor not yet identified or a combination of factors. With a pattern of improved crop productivity clearly established for no-tillage in longer-term studies for cotton as well as other crops (Bruce et al., 1995), efforts to identify mechanisms involved become appropriate. An area that has received scant attention in no-tillage cotton research is the possible contribution of mycorrhizae to the growth and productivity of the crop.

In mycorrhizal associations, fungi of the family *Endogenaceae* colonize roots of host plants. Most plant families form mycorrhizal associations, including cotton, corn (*Zea mays* L.), wheat (*Triticum aestivum* L.) and many weed species present between crops or concurrent with the crop. In these associations the hyphae of the fungal species invade plant roots and form arbuscules, which facilitate ready exchange of nutrients between the host and fungus, resulting in the association known as VAM (Vesicular Arbuscular Mycorrhizae). This association can be parasitic, benign or beneficial, but it is commonly mutualistic with the fungus receiving energy from the plant. The plant, in turn, may receive several benefits from the association. Rich and Bird (1974) reported that early-season root and shoot growth of cotton was increased in the presence of mycorrhizal fungi and that these plants flowered and matured bolls earlier. Zak et al. (1998) suggest that the fungus forms a hyphal network in the soil that can serve as an extension of the plant root system. Thus, a seedling that is colonized early can explore a much greater soil volume than is possible with a newly developing root system. Inorganic ions such as P and Zn are absorbed by the fungus and transferred to the plant. This improvement of P nutrition is a critical factor in soils with low P content. In turn, this can lead to reduced fertilizer requirements and more efficient use of soil nutrients (Marschner and Dell, 1994).

The hyphal network may also transport moisture to the plant, replacing water lost through transpiration and better maintaining plant turgor during dry periods. Mycorrhizal plants recover faster following moderate water deficits (Safir et al., 1971). This also implies that VAM plants may exhaust stored soil moisture more thoroughly than plants without an extensive hyphal network in place. The colonized plants may also avoid some stresses caused by nematodes (Hussey and Roncadori, 1982) and some plant diseases (Linderman, 1992). Tillage fragments the hyphal network so that it must be reestablished as the crop develops. With no-tillage, an existing network remains intact and may be exploited by seedling plants (Zak et al., 1998). The study reported here was initiated to investigate differences in cotton growth, nutrient uptake and VAM colonization as influenced by tillage practices.

MATERIALS AND METHODS

No-tillage following a killed wheat cover crop and conventional tillage cotton plots established in 1988, as described by Triplett et al. (1996), were used in these studies. The cotton was planted in early May 1996. The treatments described below were imposed on individual plots and/or plants within the study area.

Plant Development

Node counts and plant height measurements were begun 5 June when plants were at the four-node stage and approximately 5 in. tall. Measurements were continued on a weekly basis until 6 July.

[1]Area Extension Agent, Prof. Plant and Soil Sci. Dept., Agronomist USDA-ARS National Sedimentation Lab., Prof. Plant Path., Prof. Biochemistry and Head MAFES Experimental Statistics.

Root Colonization

Root tissue samples were selected at random from both tillage treatments in two blocks. Block A had a depth to fragipan of 34 in., a 3 to 4% slope and a history of equal yields for both tillage systems. Block B had a 5 to 6% slope, a fragipan depth of 22 in. and a yield history of no-tillage greater than conventional. Plants were sampled on 29 June at the 10-node stage. Five 1-cm sections of root tissue were selected from each of four plants in each tillage system. Root segments were stained, and colonization sites per cm of root length were recorded.

Hyphal Network and Phosphorus Uptake Studies

Three days after emergence, the following treatments were imposed on 10 individual seedlings in both tillage blocks: 1) no disturbance, 2) a 4-in.-diameter core cutter used to cut around the plant and a 6-in.-deep core removed, wrapped in nylon mesh with 60µ diameter openings and replaced and 3) core cut as in 2) but not removed. The nylon mesh openings were small enough to exclude roots but permitted hyphal penetration. To assess the hyphal network, plants were allowed to develop until mature with open bolls. The fabric was then removed, stained and examined for mycorrhizal hyphae. Counts of a single fabric sample from each plant were made within a 1000µ microscope reticle scale, rotating the eyepiece to create a circle of 1000µ. Each hyphal strand crossing a fabric pore was counted and recorded.

In the phosphorus uptake study, 10 days after emergence one microcurie of ^{32}P orthophosphate was injected 1 in. deep, 6 in. from individual cotton seedlings in treatments one, two and three described above. At the initial sampling, plants had only one fully formed leaf. This increased to two by the last sampling. Leaves from four plants were sampled one, four and eight days after ^{32}P application by cutting four 1-cm-diameter discs from tissue of each leaf. The amount of radioactivity taken up by the leaves was determined by scintillation spectroscopy.

Physiological Evaluations

These studies were done with a portable Li-Cor LI-6400 Photosynthesis System through courtesy of the MSU Crop Simulation Laboratory. The data were collected on 13 August 1996 under clear skies with temperatures in the range of 89 to 91 degrees F. Data collected included evaluations of stomatal conductivity, transpiration and level of photosynthesis.

RESULTS

In preliminary results from these studies, the mean node number for conventional tillage and no-tillage plants were similar (4.2 and 4.3, respectively). Initial plant heights were significantly different (5.0 vs. 5.8 in., respectively) for till and no-tillage. During the measurement period, no-tillage plants developed a node each 4.4 days vs. 4.7 days for plants in tilled soil. Plants in tilled soil grew significantly more slowly (0.54 in./day) than no-tillage plants (0.83 in./day). Although seedlings emerged in both tillage systems at the same time, plants in the no-tillage treatment grew taller and developed more rapidly than those in the tilled area. Vivekanandan and Fixen (1991) reported a similar vegetative growth response in corn which they attributed to mycorrhizal activity.

In the colonization study, the overall VAM colonization intensity was greater for no-tillage in the deeper soil (Table 1). However, the colonization pattern shown here does not explain the previously observed crop yield pattern of equal yields for both tillage systems in area A. Little information is available to indicate how degree of colonization influences mycorrhizal symbiosis.

In the hyphal network study, 34 hyphae/1000µ circle crossed the nylon mesh barrier with no-tillage. This was significantly greater than the 9 hyphae/1000µ circle in the tilled treatment. By the time the mesh and plants were removed, the plant root system completely occupied the confines of the mesh cylinder. The greater hyphal counts for no-tillage indicate that the hyphal strands were more numerous in the untilled soil, complementing the greater colonization intensity shown in Table 1. This supports, but does not confirm, the presence of a more established hyphal network in untilled soil.

In the phosphorus uptake study, no radioisotope activity level significantly greater than background was detected until eight days following injection of the tracer and then only for the uncut treatment (Table 2). Since P is immobile in the soil, the isotope was accessed by the plant either by root uptake or transported through VAM hyphae. Lack of uptake for the cut treatment supports the premise that the hyphal network was disrupted by cutting and was not reestablished and functional when the small plants were sampled.

Results from the physiological measurements are shown in Table 3. The no-tillage cotton plants were more actively transpiring at the time measurements were taken. This suggests that plants under no-tillage were able to obtain more moisture from the soil than under conventional tillage; however, the level of photosynthesis was similar for the two tillage treatments.

Results from the studies with cotton reported here compare favorably with published reports dealing with VAM and other crops. While no cause-and-effect relationships are definitely established, evidence is such that the role of VAM in no-tillage cotton production warrants further exploration.

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Table 1. Colonization of cotton roots by mycorrhizal fungi under no-tillage and conventional-tillage culture.

Area	Tillage Method	
	No-tillage	Conventional
	------------sites per/cm root------------	
A	12.25a[1]	3.10c
B	6.35b	4.90bc
Mean	9.3	4.0
LSD (0.05) = 2.37		

[1]Means not followed by the same letter are different at the 0.05 level of probability.

Table 2. Relative amount of ^{32}P (CPM) found in leaf tissue.

Treatment	Mean
Uncut	17.43a[1]
Cut	3.73b
Mesh	2.53b
LSD(0.05)=11.21	

[1]Means not followed by the same letter are different at the 0.05 level of probability

Table 3. Evaluations of stomatal conductivity, transpiration and level of photosynthesis.

Treatment	Mean
Stomatal Conductivity	
No-Tillage	0.219a[1]
Conventional Tillage	0.171b
LSD(0.05)= 0.04	
Transpiration	
No-Tillage	3.77a
Conventional Tillage	3.18b
LSD(0.05)= 0.57	
Photosynthesis	
No-Tillage	18.85a
Conventional Tillage	17.66a
LSD(0.05)=1.42	

[1]Means not followed by the same letter are different at the 0.05 level of probability.

NO-TILLAGE SWEET CORN HYBRID RESPONSE TO CARBOFURAN (FURADAN 4 F)

R.N. Gallaher and R. McSorley[1]

INTRODUCTION

Sweet corn (*Zea mays* L.) is an economically important crop for Florida. The hot-humid climate in Florida provides an environment for off-season sweet corn production at a time when most of the U.S. is too cold for corn growth. This same environment also is favorable for large populations of insect pests, which can reduce yield and quality. Past studies have shown that the use of the insecticides Counter (terbufos) and Furadan (carbofuran), at planting of field corn, can significantly increase yield (Gallaher, 1983, 1986a,b; Gallaher and Baldwin, 1985; Espaillat and Gallaher, 1989). All of the above research in the 1980's was with the use of Furadan 15G. This granular formulation was widely used at the time but became restricted and largely unavailable and was replaced with a non-granular formulation. The granular product had the advantage of ease of application and incorporation in the seed furrow or row and was easily activated around the seed zone. The liquid product, Furadan 4F available for use at present in Florida, is thought to require more sophisticated equipment in order to obtain good activation in the seed furrow-zone.

In these earlier studies with field corn, we found that Furadan performed better than Counter under no-tillage management, but the two products were equally effective in conventional tillage systems. Another discovery was that field corn hybrids responded more favorably to the insecticide that had been used in the hybrid breeding program. It was not unusual to obtain 40 to 50 bu/acre yield increases from the use of insecticides applied in the row at planting time (Espaillat and Gallaher, 1989). These materials also show activity as nematicides (Norton et al., 1978). After the loss of the granular formulation of Furadan in Florida, sales of this product were significantly reduced.

The objectives of this investigation were to determine 1) the yield differences among five sweet corn hybrids under no-till management, 2) the effectiveness of the use of Furadan 4F formulation sprayed in a band over the corn row at planting and 3) effects on plant-parasitic nematode populations.

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MATERIALS AND METHODS

The split-plot experiment was conducted on a Arredondo fine sand on the University of Florida, Green Acres Agronomy Field Laboratory in 1997. Main plots were five sweet corn hybrids ('XPH 3084'; 'VXT 5 Forever'; 'VNE 2 Endeavor'; 'VNT 5 Punchline'; 'XPH 3105'), planted at 28,000 plants/acre, in four-row plots, 2.5 ft wide and 20 ft long. The two subplots were with the application of carbofuran (formulated as Furadan 4F) at 1.0 lb ai/acre (the labeled rate) versus a control without application of carbofuran.

The experimental site was planted to a cover crop of 'Tift Blue" lupin (*Lupinus angustifoilus* L.) in the fall of 1996. On 17 April 1997, the sweet corn was planted directly into the standing lupin with a Brown-Harden In-Row Subsoil (Strip-till) no-tillage planter, using John Deere Flexie 71 planter units. On 21 April 1997, 1.8 quarts Bicep II (mixture of atrazine and metolachlor)/acre plus 2 quarts Roundup (glyphosate)/acre were broadcast over the experiment. On 22 April 1997, the subplot Furadan treatments were imposed by spraying the 1.0 lb ai/acre treatment in a 6-in. band over the row. The Furadan was mixed with water at a delivery rate of 30 gallon liquid/acre. The experiment was irrigated within a few hours after application of Furadan with 1/3 acre-in. of water to move the Furadan into the seed zone. On 6 May, 55 lb N/acre was applied as ammonium nitrate. On 13 May 480 lb 13 (N) - 5 (P_2O_5) - 29 (K_2O) - 1 (Mg) - 2.5 (S)/acre was broadcast over the experiment. An additional 50 lb N/acre as ammonium nitrate was applied 4 June. Supplemental weed control was by hooded sprayer, post-direct application of 1.5 pints Gramoxone Extra (paraquat), with non ionic surfactant added at the rate of 1 pint/100 gallon water. Gramoxone Extra was sprayed in 30 gallon water/acre. Supplemental gun irrigation water was applied six times at approximately 1 acre-in. each time during the growing season.

The two center rows were harvested for fresh ear and stalk weight on 30 June. Subsamples were taken to determine dry matter yield. Soil samples for nematode analysis were collected over each replication and combined at planting time. Additional samples were collected 18 July from all plots. Each nematode sample consisted of six cores of soil (1 in. diameter and 8 in. deep) collected in a systematic pattern and then combined into a plastic bag for transport. In the laboratory, a 100-cm^3 soil subsample was removed for nematode extraction using a modified sieving and centrifugation procedure (Jenkins, 1964). Extracted nematodes were identified and counted under an inverted microscope. All data were analyzed by an analysis of variance for a split-plot design, followed by mean separation by F test or Duncan's multiple-range test as appropriate.

RESULTS AND DISCUSSION

All sweet corn hybrids responded to application of Furadan (Table 1). Averaged over all hybrids, fresh ear weight was 25% greater from the application of Furadan compared to the control. This same statistic for fresh stalk weight was a 35% yield increase from application of Furadan. Fresh ear yield appeared to be greatest for XPH 3084, which was equal to VNE 2 Endeavor. Lowest yields were obtained by XPH 3105. Average fresh ear yield for VNE 2 was almost 40% greater than that of XPH 3105, and with the application of Furadan the difference was even greater (almost 45%) (Table 1).

In contrast to what one might expect, Furadan did not reduce nematode numbers as measured 18 July. In fact, root-knot nematode numbers were over 90% greater in plots receiving Furadan compared to the control plots (Table 2). However, of the two highest fresh ear yielding hybrids, VNE 2 Endeavor, had significantly lower root-knot nematode counts compared to XPH 3084.

Our data show that sweet corn hybrid selection is critical if yield is a major factor under consideration (Table 1). With yield increases as much as or more than 35% from the application of Furadan, it is obvious that this is one management input that requires consideration by growers, under conditions of this experiment. These sweet corn yield responses to application of Furadan are similar to those found for field corn hybrids (Gallaher and Baldwin, 1985; Gallaher, 1983, 1986a,b; Espaillat and Gallaher, 1989). No information was available regarding type of pesticide used in the breeding and development of the sweet corn hybrids used in this study. It is also evident that Furadan impacted insects or other pests in these sweet corn hybrids other than the four nematodes measured in this investigation. It appears that application of Furadan resulted in an environment that stimulated better plant growth, which in turn resulted in the healthier plants being able to tolerate larger populations of root-knot nematodes. This has been observed and reported for other crops and cropping systems (McSorley and Gallaher, 1997).

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Table 1. No-till sweet corn yield for five hybrids at two rates of carbofuran (Furadan 4F).

	Carbofuran rate		
Hybrid	1 lb ai[1]	0 lb ai	Average
	----- Fresh ear weight, ton/acre -----		
XPH 3084	5.37	4.33	4.85 a
VNT 5 Forever	4.38	3.86	4.12 b
VNE 2 Endeavor	5.01	3.70	4.36 ab
VNT 5 Punchline	3.57	2.77	3.17 c
XPH 3105	3.47	2.85	3.16 c
Average	4.36	3.50 *	
	---Fresh stalk weight, ton/acre---		
XPH 3084	8.02	7.23	7.63 a
VNT 5 Forever	7.33	5.06	6.20 b
VNE 2 Endeavor	6.56	4.52	5.54 b
VNT 5 Punchline	6.18	4.04	5.11 b
XPH 3105	3.34	2.48	2.91 c
Average	6.29	4.67 *	
	-------Dry ear weight, ton/acre-------		
XPH 3084	0.93 c	0.81 a NS	0.87
VNT 5 Forever	1.32 b	0.81 a *	1.07
VNE 2 Endeavor	1.61 a	0.92 a *	1.27
VNT 5 Punchline	1.14 bc	0.74 a *	0.94
XPH 3105	1.04 c	0.68 a *	0.86
Average	1.21	0.80	
	------Dry stalk weight, ton/acre------		
XPH 3084	1.86	1.87	1.86 a
VNT 5 Forever	1.89	1.26	1.58 ab
VNE 2 Endeavor	1.64	1.32	1.48 b
VNT 5 Punchline	1.79	1.11	1.45 b
XPH 3105	1.00	0.69	0.84 c
Average	1.64	1.25 *	

Data are averages of five replications. Main effect averages in columns (a,b) not followed by the same letter are different (P = 0.05), according to Duncan's multiple-range test. Sub-effect carbofuran with * or NS for differences at P = 0.05 or not different at P = 0.05, respectively, according to F test, except for the interaction for dry ear weight, in which case LSD was used (LSD = 0.23).

[1]Carbofuran was formulated as Furadan 4F.

Table 2. Effect of carbofuran (Furadan 4F) treatment and sweet corn hybrid on population levels of plant-parasitic nematodes.

	Nematodes per 100 cm³ soil			
		18 July		
Hybrid	1 April[1]	+ carbofuran[2]	- carbofuran	Average
		Ring nematodes, *Criconemella* spp		
XPH 3084		123	138	130 a
VNT 5 Forever		154	182	168 a
VNE 2 Endeavor		170	195	183 a
VNT 5 Punchline		122	100	111 a
XPH 3105		214	192	203 a
Average	128	157	161 NS	
		Root-knot nematodes, *Meloidogyne incognita*		
XPH 3084		322	130	226 a
VNT 5 Forever		250	123	186 ab
VNE 2 Endeavor		95	39	67 b
VNT 5 Punchline		55	61	58 b
XPH 3105		59	51	55 b
Average	14	156	81 *	
		Stubby-root nematodes, *Paratrichodorus minor*		
XPH 3084		5	2	3 a
VNT 5 Forever		4	7	5 a
VNE 2 Endeavor		9	5	7 a
VNT 5 Punchline		2	6	4 a
XPH 3105		5	2	3 a
Average	9	5	5 NS	
		Lesion nematodes, *Pratylenchus* spp		
XPH 3084		35	36	35 a
VNT 5 Forever		43	39	41 a
VNE 2 Endeavor		22	49	36 a
VNT 5 Punchline		53	57	55 a
XPH 3105		26	37	31 a
Average	10	5	5 NS	

Data are means of five replications. Main effect averages in columns (a,b) not followed by the same letter are different (P = 0.10), according to Duncan's multiple-range test. Sub-effect carbofuran with * or NS for differences at P = 0.10 or not different at P = 0.10, respectively, according to F test. No interactions were significant at P = 0.10.

[1]Data from 21 April pooled across all treatments; average of five replications.

[2]Carbofuran (Furadan 4F) treatments: + = 1.0 lb ai/acre; - = untreated control.

SWEET CORN RESPONSE TO YARD WASTE COMPOST AND LUPIN HAY FERTILIZER TREATMENTS

R.N. Gallaher, J.D. Greenwood and R. McSorley[1]

INTRODUCTION

The amount of municipal solid waste produced annually in Florida grew to approximately 50 million tons in 1992. This represents over 7.9 lb/resident/day and is twice the national average of about 4 lb/person/day (Smith, 1994). Biodegradable organic waste that could be composted comprises almost 60% of the total municipal solid waste. Compostable organic matter in municipal solid waste includes such things as yard trimmings, paper, fast foods, animal manure, crop residues and food processing residuals. Yard waste trimmings make up 7.4 million tons annually in Florida (Smith, 1994). Should all yard waste trimmings be composted, about 4 million tons of compost could be produced annually. In the U.S., federal law prohibited the use of unlined landfills by 1994 (Kidder, 1993). Florida law restricts the disposal of organic yard waste in lined landfills. These laws have encouraged a large industry to develop in Florida, whose objective is to produce wood chip mulch and compost from yard waste, often called yard waste compost (YWC). These products should be environmentally safe to apply to farmland and result in potential benefits not only to the farmer but also to society as a whole. For example, YWC can be applied in large quantities to farmland to help improve soil properties and crop yield (Gallaher and McSorley, 1994, 1995; Giordano et al., 1975; Kluchinski et al., 1993; Mays and Giordano, 1989; Mays et al., 1973; Wolley, 1995).

Nitrogen is the single-most-important fertilizer input and is required in the largest quantities for crop production (Olson and Sander, 1988). A sweet corn crop has a sufficient level of N if the concentration in the diagnostic ear leaf at full silking and tasseling is between 2.5 and 3.0% (Jones et al., 1991). Normal N fertilizer recommendations may differ significantly for crops grown on soils having received large quantities of YWC or other biodegradable organic waste product. Legumes are known to contain significant quantities of N and other fertilizer elements and can serve as sources of organic fertilizer (Wade et al., 1997; Wieland et al., 1997; Xiao et al., 1998). Soil K and Mg increased and diagnostic leaf N and P concentrations increased as cowpea (*Vigna unguiculata* L.) pod yield increased with increasing rates of lupin hay (Wieland et al., 1997). Studies showed that application of 2 to 3 tons of lupin (*Lupinus angustifolius* L.) hay/acre would maximize cowpea yield (Wieland et al., 1997; Xiao et al., 1998). In another study, bushbean pod yield reached maximum at 2 tons/acre crimson clover (*Trifolium incarnatum* L.) hay (Wade et al., 1997). The objective of this study was to investigate the changes in soil properties and impact on sweet corn (*Zea mays* L.) yield from use of YWC at five rates of lupin hay as an organic source of N and other nutrients.

MATERIALS AND METHODS

This research was conducted the fifth year (1997) following application of 120 ton YWC/acre each year for the previous four years (Table 1). A winter cover crop of 'Tift Blue' lupin was mowed closely just prior to planting sweet corn. 'Silver Queen' sweet corn was planted at 28,000 plants/acre in four-row plots, 30 in. wide and 12 ft long using a Brown-Harden in-row subsoil no-till (strip-till) planter. Seeders on the planter were John Deere Flexie 71's. The three main-plot treatments were residual YWC cumulative treatments (480 ton YWC/acre no-till; 480 ton YWC/acre conventional tillage; conventional tillage control) from the past four years. No additional YWC was applied in 1997 prior to planting this experiment. Subplots were five rates of lupin hay (0, 2, 4, 6, 8 ton/acre) as a source of organic fertilizer, either incorporated just prior to planting or side-dressed as a mulch immediately after planting. All treatment combinations were replicated four times. The crop was hand hoed for weed control as needed. Approximately 1 acre-in. of irrigation was applied six times. No chemical management inputs were made. Ear leaf samples were collected at early silking and analyzed for N concentrations (Gallaher et al., 1975). Soil samples were collected from the top 8 in. in February prior toplanting corn and in August following corn harvest. Soil samples were analyzed for extractable nutrients, pH, organic matter and cation exchange capacity. Soils were further analyzed for plant-parasitic nematodes using appropriate procedures (McSorley and Gallaher, 1997; and Jenkins, 1964). All data were analyzed by analysis of variance for a split-plot design, followed by mean separation by Duncan's multiple-range test.

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RESULTS AND DISCUSSION

The residual impact of application of large quantities of YWC, including large quantities of plant nutrients and organic matter (Table 1), resulted in significant improvement in soil quality for the beginning of this investigation (Table 2). Little differences existed between the two YWC treatments, but both were several hundred percent greater in most properties than the control. This condition persisted throughout the duration of the experiment, as evidenced by the summer soil test that followed (Table 2). It is obvious that the previously applied YWC should have a significant impact on crops growing under these conditions.

Yield of fresh and dry sweet corn ears shows that YWC was effective in increasing yield as evidenced by the intercept for the three YWC treatments (Fig. 1). Yield was highest for the YWC treatment when corn was grown under no-tillage management, intermediate for YWC conventional tillage and least for the control. These differences among the three YWC treatments were consistent across all five lupin hay rates (Fig. 1). Data show that maximum fresh ear yield was achieved at about 2 ton lupin hay/acre for YWC no-till treatment, about 4 ton lupin hay/acre for YWC conventional tillage treatment and about 6 ton lupin hay/acre for the conventional tillage control treatment. One possible explanation for the higher yields for YWC no-till treatment is the likely conservation of soil water from the lack of soil disturbance as well as lupin hay mulch benefits. Lupin hay on the soil surface would also result in slower release of plant nutrients in the hay, and thus reduce the potential for excessive leaching of nutrients out of the root zone during heavy rainfall events, as compared to incorporation.

Nitrogen concentration in the ear leaf (Table 3) was highly correlated with ear yield (Fig. 1) and was directly caused by increasing rates of lupin hay (Table 3). Sufficiency levels (Jones et al., 1991) for N in the ear leaf were achieved for both YWC treatments at 2 ton YWC/acre but required 6 ton YWC/acre for the control. This evidence, along with yield data, further supports the fact that residual effects of YWC not only improve soil quality but also provide an environment for increased crop yield and leaf quality. It also indicates that lupin hay is a possible source of organic fertilizer in all of the YWC treatments.

Nematodes were not affected either by YWC treatments or by the application of lupin hay (Table 4). Significant quantities of ring and root-knot nematodes were present, and both increased in numbers by the end of the crop season. Therefore, yield differences in this study were not the result of the nematodes measured.

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Table 1. Analysis of yard waste compost used on the Green Acres Agronomy Field Laboratory research plots.

	Year			
Analysis	1993	1994	1995	1996
DM %[1]	45.1	49.8	50.7	57.7
OM %	48.2	59.2	42.2	52.2
C %	33.5	31.3	33.5	32.0
N %	0.81	0.91	0.98	0.63
C:N ratio	41.7	34.4	36.4	50.8
pH chopped	6.2	7.5	---	6.5
pH ground	6.3	7.1	7.0	6.2
Ca %	3.43	3.41	1.14	1.47
Mg %	0.18	0.19	0.07	0.17
K %	0.22	0.29	0.14	0.31
P %	0.17	0.18	0.08	0.15
Cu ppm	23.0	18.0	18.0	22.0
Fe ppm	1953.0	1825.0	2608.0	2615.0
Mn ppm	180.0	188.0	75.0	97.0
Zn ppm	102.0	118.0	138.0	148.0

[1]DM % = dry matter; OM % = organic matter in DM; chopped = compost samples were chopped into coarse particles using a grinder; ground = sub-samples 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. The source of the compost was Wood Resource Recovery, Gainesville, Florida, from 1993 to 1995 and Enviro-Comp Services Inc., Jacksonville, FL in 1996.

Table 2. Mehlich I extractable elements, Kjeldahl N and other soil analyses after yearly application of 120 ton yard waste compost/acre/year from 1993 to 1996.

				Cumulative Yard Waste Compost-YWC (120 ton/acre/year)		
Analysis	Unit	LSD	CV	No-till 480 ton/acre	Conv-till 480 ton/acre	Conv-till 0 ton/acre
Winter 1997, no YWC added in 1997, test prior to planting sweet corn						
N	ppm	448	21.7%	1613	1530	442
P	ppm	12	6.3%	140	132	67
K	ppm	15	20.0%	52	49	25
Na	ppm	4.3	15.2%	20	19	10
Ca	ppm	566	21.4%	2163	2042	374
Mg	ppm	36	17.7%	158	151	46
Cu	ppm	0.14	19.6%	0.30	0.33	0.61
Fe	ppm	1.03	14.3%	3.8	4.5	4.1
Mn	ppm	1.74	13.0%	10.5	9.9	2.8
Zn	ppm	2.57	13.6%	14.6	14.1	4.0
pH		0.15	1.3%	6.9	6.8	6.6
BpH		NS	0.3%	7.88	7.86	7.86
OM	%	1.21	21.4%	4.38	4.18	1.31
CEC	meq/100g	3.18	18.6%	13.35	12.80	3.5
Summer 1997, test following sweet corn harvest						
N	ppm	440	23.2%	1063	1123	428
P	ppm	22	11.6%	122	126	84
K	ppm	NS	41.6%	40	32	37
Na	ppm	9.6	15.1%	44	37	30
Ca	ppm	676	30.2%	1709	1834	336
Mg	ppm	45	28.7%	115	121	39
Cu	ppm	0.20	31.2%	0.30	0.33	0.52
Fe	ppm	2.47	16.1%	7.3	8.5	10.8
Mn	ppm	3.29	22.1%	10.1	11.2	4.5
Zn	ppm	4.05	23.6%	12.2	13.4	4.1
pH		0.20	2.2%	6.8	6.7	6.2
BpH		NS	0.3%	7.83	7.82	7.79
OM	%	0.64	21.5%	4.14	3.82	1.26
CEC	meq/100g	3.96	25.5%	11.15	11.86	3.89

Table 3. Nitrogen concentration in ear leaf of 'Silver Queen' sweet corn from yard waste compost and lupin treatments.

	Yard Waste Compost Treatments		
Lupin Hay	No-Till	Conv-Till	Control
tons/acre	-------------------------	% N	-------------------------
0	2.40 L	2.49 L	1.87 L
2	2.51 S	2.62 S	2.43 L
4	2.71 S	2.73 S	2.49 L
6	2.82 S	2.83 S	2.74 S
8	2.74 S	2.70 S	2.74 S

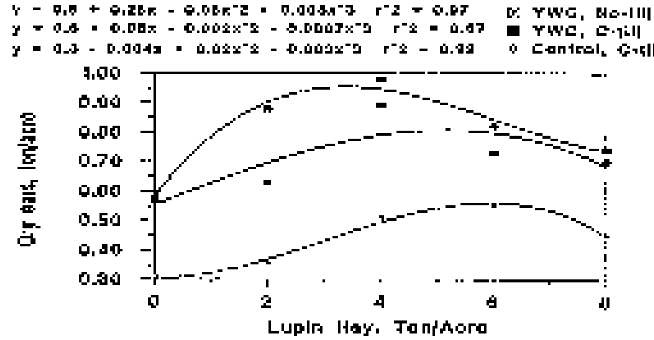
LSD (P = 0.05) = 0.28; CV = 7.4%; No-till and Conv-till treatments received a cumulative total of 480 tons yard waste compost/acre in 120 ton/acre/year increments from 1993 to 1996. No compost was applied in 1997. L = low and S = sufficient levels of N in ear leaf according to Jones et al., 1991.

Table 4. Effect of yard-waste compost on nematode population levels in plots of 'Silver Queen' sweet corn, 1997.

	Sampling Date	
Compost Treatment	6 March	28 July
	Nematodes per 100 cm^3 soil	
	Ring (*Criconemella* spp.)	
Mulch, No-till	66	143
Incorporated, Conventional-till	66	399
Control, Conventional-till	105	328
	Root-knot (*Meloidogyne incognita*)	
Mulch, No-till	24	222
Incorporated, Conventional-till	10	172
Control, Conventional-till	10	172
	Stubby-root *(Paratrichodorus minor)*	
Mulch, No-till	1	1
Incorporated, Conventional-till	0	4
Control, Conventional-till	2	3
	Lesion (*Pratylenchus* spp.)	
Mulch, No-till	12	11
Incorporated, Conventional-till	20	24
Control, Conventional-till	31	25

Data are means of four replications. No significant treatment effects at P < 0.10.

Compost applied as mulch or incorporated, both treatments at 480 ton/acre.



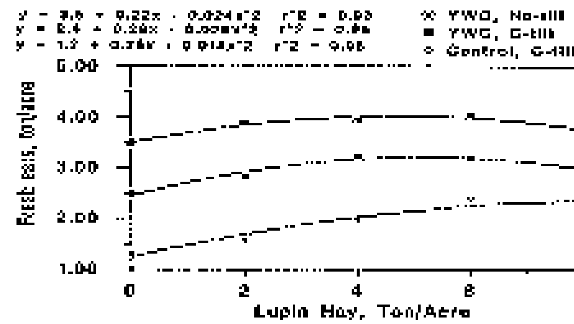


Fig. 1. Silver Queen sweet corn, fresh and dry ear weights; YWC = yard waste compost; No-till = strip-till; C-till = conventional tillage; the YWC treatmenst were from residual applications from the previous four years.

INFLUENCE OF TILLAGE SYSTEM, PLANTING DATE AND CULTIVAR SELECTION ON SOIL WATER AND SOYBEAN YIELD UNDER DRYLAND SOYBEAN PRODUCTION

E.C. Gordon, T.C. Keisling, D.M. Wallace, L.R. Oliver and C.R. Dillon[1]

ABSTRACT

Experiments were conducted at the Northeast Research and Extension Center (NEREC) at Keiser, Arkansas, in 1995 and 1996 to determine the influence of tillage system, planting date and cultivar selection on soil water storage, soybean (*Glycine max*, L. Merr.) yield and economics. The soil series was Sharkey silty clay. 'Williams 82', 'Manokin' and 'RA 452' soybean cultivars were planted in mid-April, and RA 452, 'Pioneer 9592' and 'Pioneer 9641' were planted in mid-May, mid-June and mid-July. The cultivars were stripped in three production systems consisting of no-till, fallow and conventional. Soil water levels were monitored gravimetrically in each tillage system weekly to a depth of 60 cm. The Sharkey silty clay maintained high soil water storage of 8 to 10 cm in the 0- to 60-cm depth. Sharkey silty clay was able to maintain high soil water for April- and May-planted soybean. The adequate soil water resulted in high yields for April- and May-planted soybean with the early maturity-group cultivars, Williams 82 and RA 452. Delayed planting dates conserved soil water and resulted in the highest soybean yields in June- and July-planted soybean with Pioneer 9592 and Pioneer 9641. The June no-till production system had the highest costs because of high herbicide usage. The highest net returns corresponded to the highest soybean yields. Overall, under a conventional production system on a Sharkey silty clay, the most profit was obtained when an early maturity group soybean was planted in April or May.

INTRODUCTION

Dryland soybean production encompasses approximately 65% of soybean (*Glycine max*, L. Merr.) grown in Arkansas. The low profitability of soybean relative to some other enterprises has resulted in increased interest in minimum input production systems. The common occurrence of a drought in the mid-South from mid-July to mid-September has contributed to low and stagnant yields in dryland soybean (Bowers, 1995; Heatherly, 1996). Commonly planted Maturity Group V and VI cultivars are in the critical reproductive stages during the late-season drought, and their yield potential can be greatly reduced by these droughts (Miller, 1994). Dryland producers subjected to the possibility of drought during a growing season require a production system to avoid or tolerate the effect of a drought. Manipulation of practices such as tillage system, planting date and cultivar selection could potentially increase soybean yield under dryland conditions.

Tillage Practices

Typical soybean production in the mid-South includes some type of mechanical tillage for seedbed preparation (Bowers, 1995). The general purpose of conventional tillage is to control weeds and create a favorable environment for seed emergence and plant growth. Conventional tillage provides a tilled soil layer of 15 to 25 cm deep. No-till is a cropping system in which the soil is left undisturbed prior to planting, and weed control is accomplished by herbicides. No-till systems are associated with conservation tillage, which is defined as a tillage and planting system that maintains at least 30% of the soil surface covered by residue at the time of crop emergence (Dick et al., 1989; Parsch et al., 1993).

Costs

Different management practices result in varying costs of production. Webber et al. (1987) noted that no-till production systems reduce soil erosion, decrease overall fuel consumption and equipment costs and conserve soil moisture. Although no-till generally saves fuel, labor and machinery costs, total costs may be higher due to increased herbicide expenditures as compared to conventional systems (Letey, 1984).

Planting Date

Soybean production in the mid-South has been primarily limited to Maturity Group V and VI cultivars, which are planted in May and June. Yield reductions due to drought stress occur in these cultivars quite often, because they are blooming, setting pods and beginning seed fill during July and August when there is a high probability of soil moisture deficit. Changing the planting date to an earlier or later time would shift the time when soybean plants bloom, set seed and mature, thus creating the possibility that moisture stress could be avoided during these critical periods. In the mid-South, higher rainfall amounts occur in the spring and fall with the greatest spring rainfall occurring from April to early June. This corresponds with early bloom and pod set in April-planted, early maturity, indeterminate and determinate soybean cultivars (Bowers, 1995; Miller, 1994). The early maturity group culti-

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vars experience cooler temperatures and lower evaporative demand, which reduces overall water demand. The ability of early maturity group cultivars to bloom and set pods under milder temperatures with adequate moisture increases the chance of profitable yields (Board and Hall, 1984; Heatherly, 1996; Miller, 1994).

Planting early-maturing cultivars, however, has disadvantages. Cool temperatures can delay emergence and retard growth rate. Planting dates may also be delayed due to spring rains, and a reduction in seed quality can occur (Unger and Cassel, 1991). Weed control problems at leaf drop may be associated with early Maturity Group III and IV cultivars (Dombek et al., 1995; More, 1994, Parsch et al., 1993). This can create harvesting problems and necessitate the extra cost of a desiccant application.

Research that has been conducted on late plantings of soybean has provided lower yield results for July planting dates as compared to May and June planting dates (Hancock, 1994; Moore, 1994). Some research at many locations suggests that day length, not water stress, is responsible for the declining yield after mid-June, since the yield reduction could not be eliminated with irrigation (Beuerlein, 1988; Board and Hall, 1984; Reeves and Tyler, 1996). Board and Hall (1984) have shown that a major reason for yield losses at nonoptimal planting dates is inadequate vegetative growth due to premature flowering, but yield losses due to late planting dates vary by year.

Indeterminate growth characteristics are being utilized more in southern cultivar selection. The main difference in growth habit between the determinate and indeterminate types is that indeterminate cultivars continue main stem elongation several weeks after the plants begin to flower; whereas determinate cultivars halt elongation of the main stem at the onset of flowering (Beuerlein, 1988). Indeterminate cultivars can cease growth temporarily and then restart when stress is removed. These growth characteristics may be important factors for soybean grown in the mid-South due to prolonged drought conditions.

Soil Moisture

Tillage systems influence soil water content through infiltration and runoff, evaporation and precipitation storage. Evaporation from a soil is affected by the residues left on the soil surface and by the soil properties. Tillage alters infiltration and runoff through surface residue, bulk density and soil crusting.

Soil crusts may develop on no-till and conventionally tilled soils, reducing water infiltration and increasing runoff. Water infiltration and runoff are also influenced by surface residue and bulk density. Soils with high residue prevent the formation of soil crusts. If soil residue is adequate, surface infiltration will be enhanced. Soils with low residue levels require tillage for enhanced infiltration (Unger and Cassel, 1991).

Conventional tillage may promote degradation of the soil physical condition by reducing the soil pore volume and water storage area (Letey, 1984). Tillage increases the susceptibility of the soil to compaction by traffic or natural consolidation. Plants growing in soils with tillage pans may undergo severe moisture stress after 5 to 8 days without rainfall (Reeves and Tyler, 1996).

Conservation tillage results in greater compaction of the top 10 cm of soil as compared to conventional tillage. However, this compaction can prevent more severe compaction at greater depths (Reeves and Tyler, 1996). Soils with less-available moisture favor high yields in early-maturity group cultivars whereas deep soils favor high yields in late maturity group cultivars (Miller, 1994).

The objective of this research was to evaluate cultural practices, including tillage practice, planting date and cultivar selection, for potential to increase soybean yield and profitability under dryland conditions.

MATERIALS AND METHODS

Field experiments were conducted in 1995 and 1996 at the Northeast Research and Extension Center at Keiser, Arkansas, on a Sharkey silty clay soil series. The experimental design was a split-split strip plot with four replications. The individual plot size was 3 m wide by 7 m long with 9-m alleys. The main plot was four planting dates: mid-April, mid-May, mid-June and mid-July. Subplots were tillage levels: no-till, fallow and conventional. Three soybean cultivars were stripped within each tillage level. The tillage subplots had a 3-m fallow border between tillage systems. The plots were not irrigated. Weather data were collected at the location, and all production inputs were recorded by planting date and production practice.

Tillage levels were based on practices that potentially conserve soil moisture. No-till plots were not disturbed from the fall prior to experiment establishment until the conclusion of the experiment. The fallow treatments were tilled 3 to 5 cm deep with a roto-tiller following each rainfall event prior to planting. Conventionally tilled plots were tilled 10 to 15 cm deep in the fall and prior to soybean planting or when vegetation reached a height of 15 to 24 cm.

Herbicide programs were designed for complete weed control (Table 1). Two weeks prior to planting, the no-till system received a burndown application of glyphosate (Roundup Ultra®) to desiccate winter weeds and emerging summer annuals. The no-till and fallow systems then received applications of metolachlor (Dual II®)+ a premix of metribuzin and chlorimuron (Canopy®) applied preemergence. A preplant incorporated application of trifluralin (Treflan®) + metribuzin and chlorimuron (Canopy®) was applied to the conventional system. All tillage systems received fomesafen (Reflex®) as a post-emergence over-the-top application as needed for weed control during the growing season. Dates of post-emergence herbicide applications varied and are presented in Table 2.

Cultivars were selected from the Arkansas Variety Selection Program (Dombek et al., 1995) and varied with planting date (Table 3). Cultivars in Maturity Groups III and IV were selected for the mid-April planting date, and cultivars in Maturity Groups IV, V and VI were used in the mid-May, mid-June and mid-July planting dates. Both indeterminate and determinate cultivars were used in the cultivar selection.

Soybean seeds were planted flat in 18-cm row spacing with a 3-m-wide John Deere no-till drill. Seeding rate was 9 to 12 seeds/m of row. Plots were harvested with a plot combine at maturity.

Soil moisture in the tillage production systems was measured gravimetrically at planting and every week during the growing season, except after rainfall when soils were saturated. Soil samples were taken at random to a depth of 8 cm from each tillage method plot at planting and after planting in 1995. In 1996, soil samples were taken to a depth of 60 cm. Soil sampling was discontinued when the earliest maturing cultivar in the planting date reached the R6 growth stage.

Economic analysis of the experiment was conducted using the Mississippi State University Budget Generator computer program. All economic inputs were recorded and entered. Variable and total costs were generated along with net returns. The average price of soybean used in the economic analysis to calculate net returns was $5.92/bu.

All data were subjected to analysis of variance using the GLM (General Linear Model) procedure of SAS. Means were separated using Fisher's Protected LSD (0.05).

RESULTS AND DISCUSSION

Soybean yields, economic costs and net returns could be pooled over years. Environmental conditions varied little between years. Rainfall levels were higher in 1996 but did not significantly affect soil water storage or soybean yield.

Tillage level had few significant influences on soil water storage and soybean yield (data not shown). The tillage levels implemented were expected to alter soil water evaporation rates and soil water storage (Mwendera and Feyen, 1994). However, the shallow tillage operations could not be conducted immediately after rainfall due to travel and labor restrictions, and some evaporation occurred before the implementation of the fallow tillage system. Consequently, soil water samples were taken after evaporation losses in each production system.

Soil samples for soil water storage determination were taken randomly by planting date each year. As a result, years could not be combined by sampling date and will be discussed separately. Soil samples for soil water storage determination were taken from only a 0- to 8-cm depth in 1995, and there was no influence on soil water storage or soybean yields due to the shallow sampling depth. In 1996, the soil was sampled to a depth of 60 cm with a new sampling technique utilizing lubricants, and only these data will be discussed.

Planting date significantly affected soil water storage and soybean yield and will be discussed by specific planting date. Also, cultivar selection significantly affected soybean yields at the varying planting dates. Therefore, individual cultivar yields will be discussed within a planting date. Soil water sampling was taken at random across the three cultivar strips for each tillage level. Therefore, cultivars and their effects on soil water storage and economics could not be evaluated.

Soil Water Storage

In 1996, soil water storage was similar among the April, May and June planting dates (Fig. 1). Frequent rainfall replenished soil water levels until August. However, some variation in soil water levels was observed in June and in the duration of drought during each planting date.

The April planting date had the lowest soil water storage in mid-June to mid-July (Fig. 1). Since soil water utilization began in April, the April-planted soybean roots had removed soil water for the longest duration. Drought conditions did not occur until August, allowing the April-planted soybean to reach maturity before severe water stress. These results coincide with the findings of Bowers (1995) and Miller (1994).

The May and June planting dates maintained slightly higher soil water levels in June and July than the plots planted in April (Fig. 1). The May and June planting dates conserved soil water in April and May that could be used in June and July. In August, the May and June planting dates decreased dramatically in soil water. Drought conditions resulted in the use of all available soil water.

The July planting date maintained the highest soil water storage in August during the drought conditions (Fig. 1). The delayed planting date allowed soil water conservation in April, May, and June in the absence of vegetation. Previous research (Hancock, 1994) showed that weed-free areas have higher soil water storage.

Soybean Yields

The April- and May-planted soybean had the highest yields (Table 4). Soybean yields decreased when the planting date was delayed due to drought and decreasing photoperiod.

The Maturity Group III cultivar, Williams 82, yielded the highest of the April-planted cultivars. The early maturity cultivar matures during the highest soil water storage levels, and its indeterminate growth patterns can increase vegetative growth, which can increase soybean yield. Therefore, Maturity Group III cultivars can avoid water stress and produce high yields (Bowers 1995; Heatherly, 1996; Miller, 1994). The Maturity Group IV cultivars, RA 452 and Manokin, have a longer growing season, which extended the reproductive stage into drought conditions for a longer duration (Fig. 1) and affected yield.

RA 452, a Maturity Group IV cultivar with indeterminate growth, had the lowest yield of the cultivars planted in the delayed planting dates due to premature flowering (Table 4). Pioneer 9592, a Maturity Group V cultivar with determinate growth, had the highest yields and was the best-suited cultivar for the May and June planting dates. Pioneer 9641, a Maturity Group VI cultivar with determinate growth characteristics, had the longest growing season of the cultivars and the lowest yields when planted in May and June due to dry conditions during its reproductive period. However, when planted in July, Pioneer 9641 had the highest soybean yields.

Economics Costs

The conventional production system had the lowest costs (Table 5). Mechanical preplant tillage operations for weed control in conventional tillage resulted in lower production costs than equivalent herbicide programs in no-till.

The fallow production system costs were slightly higher than the conventional production system. The fallow-tillage system had shallow tillage after rainfall events of >2 cm to destroy soil crusts. Shallow tillage was often performed two or three times a month during frequent rainfall events. Thus, the high number of tillage operations increased costs in the fallow production system as compared to the conventional production system.

The no-till production system had the highest costs (Table 5), because no-till required the application of a preplant burndown herbicide for adequate weed control. The preplant burndown herbicide application was more costly than mechanical tillage, resulting in higher variable and total costs than the conventional tillage production system.

The June planting date, regardless of tillage system, had the highest variable and total costs and July the lowest of the planting dates under fallow and conventional production systems (Table 5). This was due to weed pressure, which necessitated post-emergence applications for June planting dates, while July planting dates required only preplant or preemergence herbicide applications (Table 2). The lowest production variable and total costs in the no-till production system were in April due to low herbicide costs (Table 5).

Net Returns

Production systems greatly influenced net returns (Table 6). The no-till system provided the lowest net returns due to higher herbicide costs. The slight increase in costs of the fallow production system did not affect net returns, since the fallow system had slightly higher net returns than the conventional system for all planting dates except June. The high cost of the no-till production system resulted in a decrease of approximately \$80/ha and \$62/ha in net returns as compared to the fallow and conventional production systems, respectively.

Average net returns were the highest in April and May planting dates (Table 6). After May, net returns decreased sharply, becoming the lowest in July. A relatively low range occurred in soybean yields between years, and the planting dates with the highest net returns should be used. To achieve the lowest risk in soybean production and highest average net returns, the planting dates for soybean should spread out among all the planting dates.

SUMMARY

Soil Water Storage

The Sharkey silty clay maintained approximately 8 to 10 cm of soil water to a 60-cm depth. Thus, April- and May-planted soybeans on the Sharkey silty clay potentially avoided drought stress by maturing before soil water was depleted in the root zone. Cumulative water removal of early-planted soybean resulted in low soil water levels during July and August under drought conditions. Maintaining a vegetation-free surface conserved soil water, which could subsequently be used by late-planted (June and July) soybean. This would be especially important during seasons with prolonged drought periods.

Soybean Yields

Soybean yields were influenced by planting date and cultivar selection. April- and May-planted soybean plots yielded the highest with the Maturity Group III indeterminate Williams 82 being the best for April planting. The Pioneer 9592 Maturity Group V determinate cultivar was best suited for May planting. RA 452, a Maturity Group IV indeterminate cultivar, also had high yields when planted in May. Soybean yields typically declined in June and July planting dates relative to April and May plantings. Pioneer 9592 should be planted in May. June and July planting dates should be avoided.

Economics

No-till production systems were always more expensive than the fallow or conventional production systems. Tillage operations cost less than herbicide applications for weed control. Planting dates influenced costs because of herbicide requirements with the June planting date having the highest cost. High weed pressure in June required repeated applications of postemergence herbicides and resulted in high herbicide costs. The lowest cost occurred in the July planting date, which did not have to rely on post-emergence herbicide applications.

A no-till production system resulted in approximately a \$80/ha and \$62/ha loss in net returns as compared to the fallow and conventional production systems, respectively.

The net returns at each planting date followed the same trend as soybean yields. April- and May-planted soybeans had the highest yields and highest net returns.

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Table 1. Herbicide programs.

Trade name	Common name	Method of application[1]	Rate
			kg/ha
Roundup Ultra[2]	glyphosate	PPBD	1.12
Dual II + Canopy[3]	metolachlor + chlorimuron/metribuzin	PRE	2.8
Treflan + Canopy[4]	trifluralin + chlorimuron/metribuzin	PPI	1.12
Ref lex [3]	fomesafen	POST	0.42

[1]Method of application: PPBD = preplant burndown, PPI = preplant incorporated, PRE = preemergence, POST = postemergence.
[2]Treatments used only in no-till tillage system.
[3]Treatments used only in no-till and fallow tillage systems.
[4]Treatments used only in conventional tillage systems.

Table 2. Postemergence herbicide applications.

Planting date	Herbicide	Application timing and soybean stage 1995 Date	1995 Stage	1996 Date	1996 Stage
April	Reflex	6/21	V5	6/27	V5
May	Reflex	6/21	V3	6/27	V3
June	Reflex	7/08	V2	7/14+7/25	V2+V3
July	Reflex	7/25	V2	- - -	

Table 3. Planting date and cultivar selection.

Planting date	Cultivar	Maturity group	Growth characteristics[1]
Mid-April	Williams 82	III	ID
	Manokin	IV	D
	Ring Around 452	IV	ID
Mid-May,	Ring Around 452	IV	ID
Mid-June,	Pioneer 9592	V	D
Mid-July	Pioneer 9641	VI	D

[1]ID = indeterminate; D = determinate.

Table 4. Influence of planting date and cultivar on average soybean yield.

Cultivar	Planting date April	May	June	July
	----------kg/ha----------			
Williams 82	3516	----	----	----
Manokin	3289	----	----	----
RA 452	3245	3301	2425	1193
Pioneer 9592	----	3559	2624	1565
Pioneer 9641	----	3173	2386	1753

$LSD_{0.05}$ for comparing among planting dates = 161
$LSD_{0.05}$ for comparing among cultivars = 134

Table 5. Influence of planting date and tillage system on average variable and total economic costs at Keiser (1995 and 1996).

Tillage system	Variable costs April	May	June	July	Total costs April	May	June	July
	($/ha)							
No-till	260.98	294.40	343.70	326.93	316.14	354.03	409.25	393.20
Fallow	216.67	225.19	245.05	204.22	257.67	272.86	299.54	260.81
Conv.	204.07	224.62	224.62	177.96	250.61	255.25	276.91	228.08

$LSD_{0.05}$ for comparing variable cost means among planting dates = 2.47
$LSD_{0.05}$ for comparing variable cost means among tillage systems = 2.47
$LSD_{0.05}$ for comparing total cost means among planting dates = 2.47
$LSD_{0.05}$ for comparing total cost means among tillage systems = 2.47

Table 6. Influence of planting date and tillage system on average net returns.

Tillage system	Planting date April	May	June	July
	$/ha			
No-till	412.27	358.67	164.55	-25.34
Fallow	464.28	490.91	218.37	56.71
Conv.	453.93	449.52	240.31	13.81

$LSD_{0.05}$ for comparing among planting dates 11.65
$LSD_{0.05}$ for comparing among tillage systems 12.71

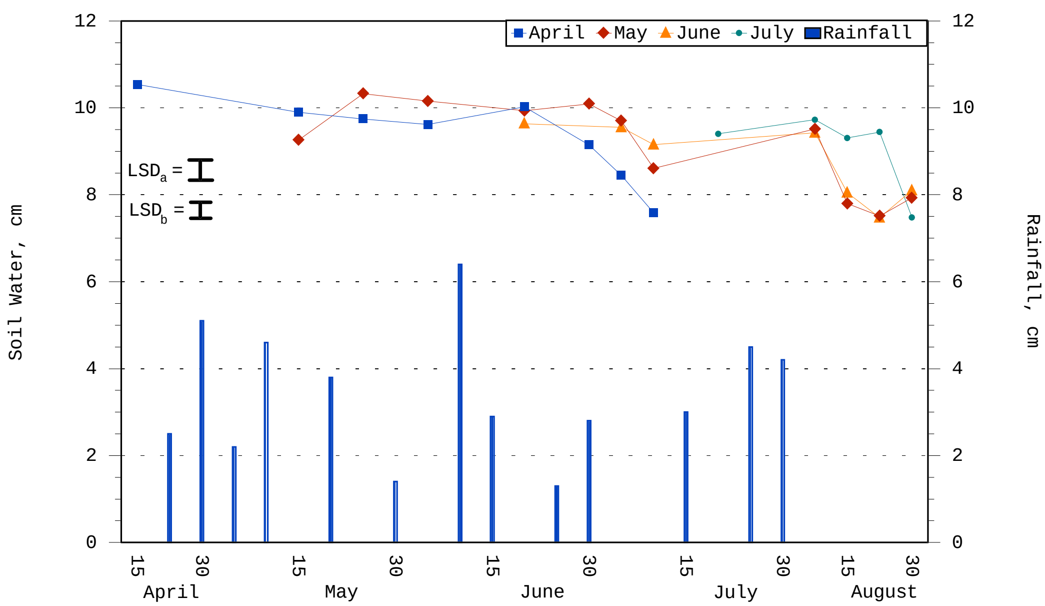

Fig 1. Influence of planting date and rainfall on soil water storage to a depth of 60 cm at Keiser in 1996. LSD (a) for comparing between planting dates. LSD (b) for comparing between sample dates.

TWO METHODS OF COMPOSTING GIN TRASH

E.C. Gordon, T.C. Keisling, L.R. Oliver and Carl Harris [1]

INTRODUCTION

A necessary situation that occurs in the cotton ginning process is the accumulation of about 200 lb of waste per ginned bale. This waste, called gin trash, has to be disposed of at some point in time. Much of the gin trash was incinerated for many years, but certain regulations, such as the Clean Air Act of 1970, have removed burning as an option. Using gin trash as a livestock feed is done to an extent, but there is some concern regarding chemical residues.

Another option in the disposal of gin trash is to spread it directly on the fields. Returning the organic material and nutrients can be beneficial, but certain problems might occur when spreading raw gin trash onto fields. Weed seed and disease, particularly Verticillium wilt, may be introduced to or increased in fields when spreading raw gin trash. The removal of these two potential problems makes the spreading of gin trash much more attractive.

An effective method of handling gin trash and reducing the problems associated with weed seed and disease organisms is to compost the material. With adequate moisture, approximately 70%, the heat generated in the composting process can be sufficient to kill weed seed (140 F for 10 days) and disease organisms (145 F for two days) (Alberson and Hurst, 1964; Griffis and Mote, 1978b; Parnell et al., 1980). Commercial contained-composting-systems have demonstrated this. However, the high cost of commercial contained-composting-systems tends to be prohibitive, so alternative composting methods have been investigated.

Windrow-composting-systems can generate the necessary heat if there is adequate volume, moisture and aeration. The aeration is usually provided by turning the composting material with some type of implement. In the humid Southern region, rainfall could conceivably supply sufficient water for initial wetting of the gin trash as well as keeping it moist for the duration of the composting process. This would eliminate a wetting step and make the overall process cheaper.

Recently, new gin trash handling methods have been developed. The Lipsey®-gin-trash-composting-system requires the compost to stay in place. The compost pile is formed in a circular pattern by rotating back and forth around a pivot point (Fig 1. top view). The rotation motion is at a constant speed so the thickness of gin trash deposited on top of the compost pile is a function of 1) amount of trash in un-ginned cotton, 2) rate of ginning and 3) current depth of compost pile (as the sides are slanted as shown in Fig. 1 side view). Uniform wetting throughout the pile is facilitated by wetting the gin trash as it is delivered to the top of the compost pile. The resulting compost pile has layers of various thicknesses that are applied at varying rates. Thus, the zone of aeration is controlled by the depth from an outside surface and the duration of the compost at this depth.

Experiments were conducted to evaluate certain aspects of windrow-composting-systems and the Lipsey® system.

MATERIAL AND METHODS

Experiment 1

In March 1977 gin trash from Mann's Gin in Lee County, Arkansas, was placed in windrows for composting. A typical windrow is approximately 40 ft long, 4.5 ft at the base, 2 ft across the top and 1.33 ft tall. The experimental design was a randomized complete block with five replications. The treatment design was a split-split plot. The main plots were timing of turning of the windrow with a root rake. Main plot treatments included 1) turned weekly or 2) turned when the temperature 6 in. below the surface reached 80 F. Main plots were split with half receiving 4.2 lb of nitrogen (N) per plot as a commercial fertilizer and the other receiving no N. The N-treated plots were then split and one-half of each plot inoculated with Roebic™ aerobic inoculum. Temperatures at 6 in. from the windrow top surface were taken daily until mid-April when composting was complete and were used to evaluate the benefit of additives in the composting process. Rainfall was the only water received by the compost piles.

Composite samples were collected before and after composting and analyzed for nutrients and selected chemicals.

Experiment 2

Composting plots were established in Lee County, Arkansas, during November 1978 to evaluate aeration methods. Two implements were compared for effectiveness of turning a windrow–a root rake and a modified combine

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(Lalor et al., 1978). The experimental design was a randomized complete block with four replications. Treatments consisted of turning the compost weekly and every two weeks by each machine. Moisture was monitored. Those plots turned with the combine had water added to the compost pile to adjust moisture to circa 70%. The plots turned with the root rake received only rainfall for wetting the compost pile. Effectiveness was determined by measuring internal temperatures as in Experiment 1.

Experiment 3

In February 1995 three gin trash compost piles that were formed during the fall of 1994, using the Lipsey® gin trash composting system, were selected for sampling and evaluating weed seed germination. Two compost piles were located in Phillips County, Arkansas, and one in Crittenden County, Arkansas. In Phillips County samples were taken from both piles to a depth of 30 in. in 6-in. increments from the surface using a bucket. Approximately 2.5 gallons of compost was removed from each depth increment in each pile for subsequent analysis for chemicals and organisms.

The compost pile in Crittenden County was sampled using a front-end bucket loader to cut into the pile 10 to 15 ft. Again, approximately 2.5 gallons of compost was collected at 5-in. increments from the compost surface to a depth of 48 in. for subsequent analysis by grabbing material from an 8-ft-long vertical face.

All samples from each location were stored in plastic bags and kept at room temperature until they were taken to the University of Arkansas at Fayetteville within one to two weeks after collection. The samples were divided into two sub-samples of approximately 1 gallon each. The subsamples were placed in containers measuring 16 in. long by 12 in. wide by 2 in. tall. The containers were placed in a greenhouse for 10 weeks. The compost in each container was kept moist and stirred every two weeks. Observations were made two to three times weekly on the number and weed species that germinated. Chemical composition was determined for N, C, P, K, Ca and Mg. The pH was also measured.

RESULTS AND DISCUSSION

Experiment 1

Neither use of a starter aerobic inoculum (Fig. 2) nor addition of N (Fig. 3) was needed to initiate the composting process. Regardless of treatment, temperatures were similar over the composting period. This indicated that no addition of inoculum or N was needed for proper composting to occur. These findings agree with those of Griffis and Mote (1978a). Heating criteria for turning the pile gave slightly higher internal temperature than just turning weekly (Fig. 4). Neither method resulted in temperatures high enough or long enough to kill Verticillium wilt fungi or weed seeds. Weeds observed growing on top of the windrows after composting was complete were annual bluegrass (*Poa annua*), large crabgrass (*Digitaria sanguinalis*), purple nutsedge (*Cyperus rotundas*), yellow nutsedge (*Cyperus esculentus*), pigweed (*Amaranthus* spp.), morningglory (*Ipomoea* spp.), horsenettle (*Solanum carolinense*) and prickly sida (*Sida spinosa*). Reproductive characteristics of certain weeds listed above make it obvious that the seed were mixed with the compost during the turning process rather than being delivered in the gin trash.

The nutrient analysis of gin trash samples is shown in Table 1 as total analysis and soil test analysis. The pH levels remained below 7, indicating aerobic composting conditions. Higher pH levels would indicate anaerobic composting that favors the conversion of N to ammonia. High temperatures enhance the volatility of ammonia (Golueke, 1972).

We observed that using natural rainfall for wetting resulted in channeling of water through selective pathways in the compost pile. As a result, some of the material was very slow in wetting and did not necessarily go through a heat. These pockets of dry material were mechanically incorporated with wetter compost during the turning process.

Experiment 2

Due to the non-uniform wetting, a modified combine (Lalor et al., 1978) that would mix and wet a windrow uniformly was built. The modified combine accelerated the composting process, as evidenced by increased early composting temperatures (Fig. 5). The temperatures were still not high enough or long enough to kill weed seeds and wilt organisms 6 in. below the compost pile surface.

Weekly mixing moves materials from the outside of the compost pile to the inside where heat can be accumulated. This should result in temperatures high enough and long enough in duration (140 F for 48 hr) to kill Verticillium wilt organisms and weed seeds between weekly turnings. Assuming that 50% of the pile is wet enough to generate sufficient heat, complete weekly mixing provides sufficient aeration and carbon supply for the composting organisms to function. After each mixing, the reduction in the compost volume containing viable diseases and weed seeds should be halved. Therefore, 15 mixes or weeks would be required to produce a 99.99% compost with essentially no weeds or diseases, which is about twice as long as it took our composting operation to be completed. Hence, a different method other than windrow-composting with mechanical mixing will be necessary.

Experiment 3

No viable weed seeds were detected from the compost samples obtained from the compost piles made by the Lipsey® composting system. Two months after the ginning season, temperature within the pile was too hot for more than 10 to 15 seconds contact with the bare hands. Since no weed seeds germinated in our greenhouse test, it appears that the weed seed viability was destroyed from the heat of composting. The outside of the pile, which had not gone through a heating process, had several weeds growing on it. This might be easily sterilized using a solar technique, such as covering the entire pile with a sheet of black plastic for a few days.

The carbon/nitrogen ratio (C/N) tends to increase at the deeper sampling depths, indicating an anaerobic composting process with a possible loss of N as ammonia (Table 2). The pH levels being greater than 7 at depths greater than 6 in. confirm anaerobic conditions. The anaerobic composting process appears to generate sufficient heat for sterilization but will result in a compost of a fibrous consistency with a bad odor.

CONCLUSIONS

The results presented here indicate that the windrow composting system does not solve the two problems of Verticillium wilt or weeds associated with gin trash. Otherwise, the compost obtained is quite satisfactory as a product. The Lipsey® composting system produced a compost pile whose outer layer had problems with weed seed and Verticillium wilt survival. These problems could be easily eliminated by using a solar sterilization process consisting of covering the pile with a continuous sheet of plastic. Otherwise, the composting process turns anaerobic within a couple of feet of the surface, resulting in incomplete composting and in offensive odors.

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Table 1. Analysis of gin trash used in 1977 experiments.

Total Analysis	N	P	K	Ca	Mg	Na	Zn	Fe	Mn	As	pH
	------%						-------ppm				
Before Composting	1.66	0.29	0.78	1.90	0.34	0.05	41.0	2218	343	2.0	6.9
After Composting	1.04	0.14	0.52	0.51	0.21	0.02	-	1280	313	-	6.2

Soil Test Analysis	Nitrate-N	P	K	Ca	Mg	Na	EC	pH
	------lb/acre						μmhosx10^3	
	1620	160+	2740	1699	710	193	1.4	6.2

Table 2. Chemical analysis of compost from a Lipsey® system for handling gin trash in Phillips County (PC) and Crittenden County (CC), Arkansas.

Depth from compost surface	N PC	N CC	C PC	C CC	C/N PC	C/N CC	P PC	P CC	K PC	K CC	Ca PC	Ca CC	Mg PC	Mg CC	pH PC	pH CC
in.	------%															
0-6	4.0	4.0	26.70	30.2	6.8	7.5	0.6	0.4	0.6	0.5	2.6	2.2	0.6	0.4	6.2	5.6
6-12	4.5	4.0	29.20	13.7	6.4	6.2	0.7	0.6	2.1	2.4	2.5	2.2	0.8	0.6	7.0	7.8
12-18	3.9	3.9	29.70	31.1	7.7	8.0	0.8	0.6	1.6	1.9	2.8	2.2	0.7	0.6	7.4	7.5
18-24	4.0	3.9	32.40	27.1	8.0	6.9	0.6	0.6	1.6	2.3	2.9	2.3	0.6	0.6	8.0	7.7
24-30	4.0	4.1	31.50	29.7	8.0	7.2	0.6	0.5	2.3	1.7	2.7	1.7	0.7	0.5	7.3	6.9
30-36	3.9	3.5	36.50	28.7	9.4	8.3	0.6	0.6	2.8	1.9	2.5	2.9	0.7	0.6	7.0	7.7
36-42	-	3.3	-	34.1	-	10.5	-	0.6	-	1.8	-	2.9	-	0.6	-	7.3
42-48	-	2.7	-	36.1	-	13.1	-	0.5	-	1.9	-	2.7	-	0.5	-	7.6

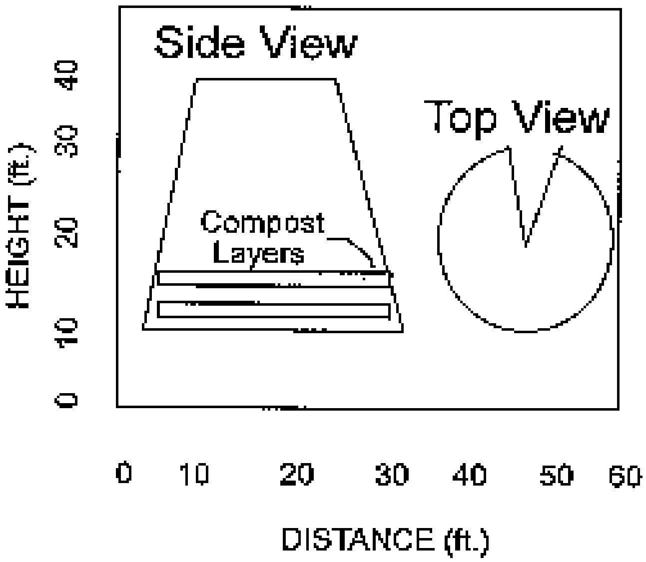

Fig. 1. Schematic diagram of a Lipsey* compost pile.

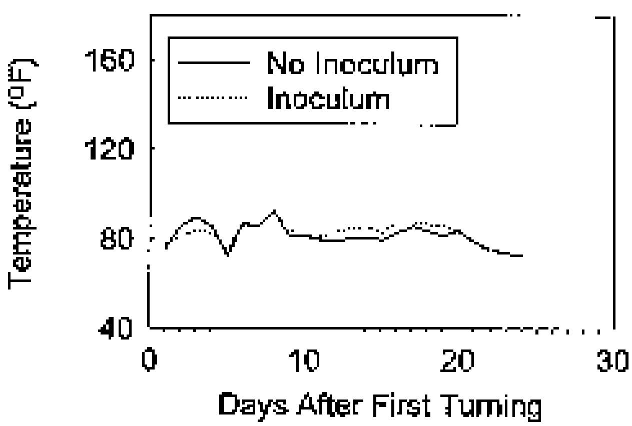

Fig. 2. Influence of starter inoculum on the composting temperature at 6 in. from the surface.

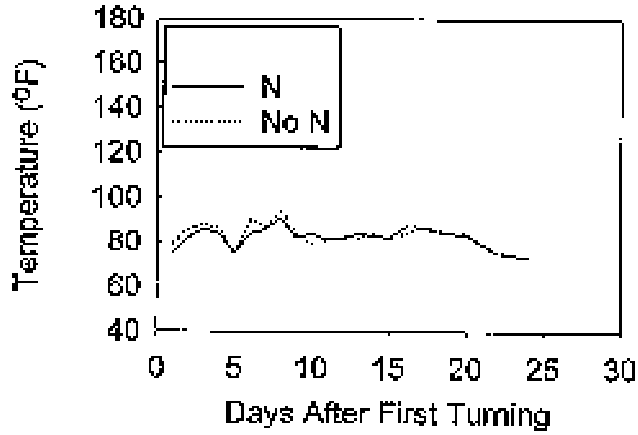

Fig. 3. Influence of N additions at the rate of 4.2 lb/48 ft of windrow on the composting temperature at 6 in. from the surface.

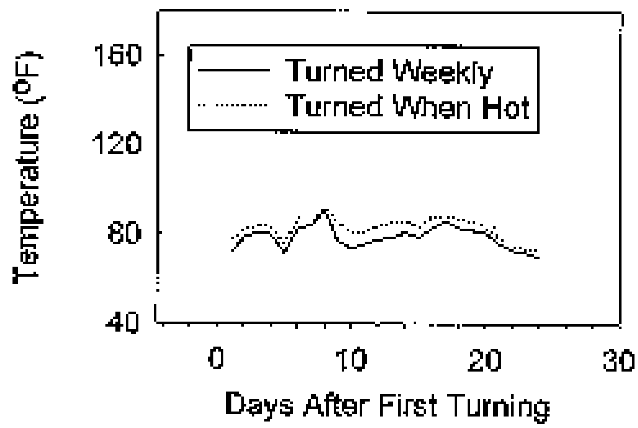

Fig. 4. The influence of turning regime on the composting temperature at 6 in. below the surface.

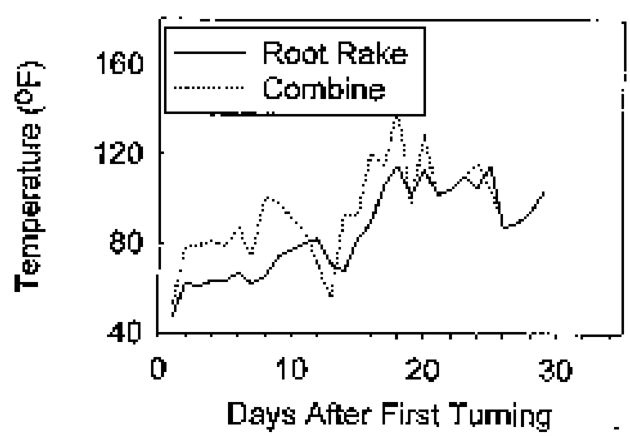

Fig. 5. The influence of turning machine on the composting temperature at 6 in. from the surface.

COMPARISON OF TILLAGE PRACTICES FOR COTTON PRODUCTION ON ALLUVIAL SOILS IN NORTHEASTERN LOUISIANA

E.M. Holman, A.B. Coco and R.L. Hutchinson[1]

INTRODUCTION

Advances in equipment and herbicide technology have contributed greatly to the increase in producer acceptance of reduced tillage practices in northeastern Louisiana. Reduced soil erosion (Hutchinson et al., 1991), increased soil organic matter (Boquet and Coco, 1993) and reduced soil moisture evaporation (Wilhelm et al., 1986) are just some of the documented benefits from no-tillage. Reduced tillage, in many instances, has also led to lower equipment and fuel costs and savings in time and labor (Laws, 1993). In addition, cover crops have been found to be an important component of conservation tillage systems (Hutchinson et al., 1991; Ebelhar et al., 1984).

Although erosion is not a serious problem on many of the clay soils in the Mississippi River Delta, cotton (*Gossypium hirsutum* L.) production has still benefitted from reduced tillage practices primarily by allowing producers to plant in a more timely fashion (Boquet and Coco, 1993). Spring tillage on clay soils often results in a cloddy, dry seedbed in which it is difficult to obtain a uniform plant stand.

On clay soils, deep tillage to relieve compaction has traditionally been considered unnecessary due to the natural shrinking and swelling that these soils undergo as the moisture content cycles from wet to dry. It has been speculated (Smith and Whitten, 1992) that while clays do not develop compaction pans typical of lighter-textured soils, they may develop compacted blocks of soil beneath the plow layer. The effect of this soil condition is to confine plant roots to the soil volume near the block surfaces. The density of the blocks prevents or severely restricts root growth into the clay block, and roots that do grow from one block surface to another are often broken when the blocks dry and shrink. Results from previous tillage studies failed to demonstrate crop response to deep tillage on clay soil (Raney et al., 1954; Saveson et al., 1958; Tupper, 1978; Heatherly, 1981). However in these studies, the tillage operations were performed in the spring when the subsoil was most likely wet from winter rainfall. Recently, Smith (1995) indicated that deep tillage in the fall, when the soil profile was dry, was beneficial for cotton growth and yield on a Tunica clay. There is a lack of information on the interaction between deep tillage in the fall and various conservation tillage practices on clay soils in Louisiana.

On the medium- and coarse-textured alluvial soils in northeastern Louisiana, compaction is a yield-limiting factor unless some form of deep tillage is performed (Crawford, 1979; Saveson et al., 1958). In northeastern Louisiana, these soils have typically been under a mono-crop production system that utilizes extensive surface tillage to control weeds, prepare seedbeds and incorporate herbicides. Although these soils are highly productive, the combination of extensive tillage and mono-crop culture have contributed to low organic matter levels (< 1.0%) in many fields. As the use of conservation tillage practices and winter cover crops has been shown to result in increases in soil organic matter levels (Hutchinson et al., 1991; Millhollon and Melville, 1991), some combination of these practices might lead to improved growth and yield of cotton on these soil types. Therefore, the objectives of this study were to: 1) determine the optimum combination of cover crop and tillage necessary to maximize cotton production while maintaining or increasing soil productivity and 2) examine the effect of deep tillage in conjunction with cover crops and reduced tillage practices on cotton production.

METHODS

A field study was initiated in the fall of 1996 on a Commerce silt loam (fine-silty, mixed, nonacid, thermic Aeric Fluvaquent) and on a Sharkey clay (very-fine, montmorillonitic, nonacid, thermic, Vertic Haplaquepts) at the Northeast Research Station near St. Joseph, Louisiana. A total of 16 treatments were established with combinations of tillage systems {no-till (NT), conventional till (CT), reduced-till (RT)), winter cover crops [winter wheat (*Triticum aestivum* L.), hairy vetch (*Vicia villosa* L.), and native vegetation], in-season cultivation, and fall sub-soiling} summarized in Table 1. Treatments were only slightly different on the two soil types with CT on the silt loam including disking in the fall and spring prior to seedbed preparation, while on the clay CT involved only hipping in the fall and spring. The RT treatments on the silt loam were hipped in the fall and spring, while on the clay the RT treatment involved hipping and rolling in the fall and no additional tillage in the spring. Experiment design for both tests was a randomized complete block with four

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replications. Plot size was four rows (40-in. row spacing) by 65 ft.

Deep tillage operations on the appropriate plots were conducted with a Paratill following cover crop planting in October 1996. Cotton cultivar 'Suregrow 501' was planted 5 May 1997 using ripple coulters mounted on the planter. Management of the cover crops prior to planting (4 weeks before planting) in the no-till plots consisted of 1) an application of glyphosate (1.0 lb ai/acre) followed by paraquat (0.75 lb ai/acre) on the wheat plots; 2) an application of paraquat (1.0 lb ai/acre) and cyanazine (0.75 lb ai/acre) followed by paraquat (0.75 lb ai/acre) on the vetch plots; 3) an application of paraquat (0.75 lb ai/acre) and cyanazine (0.75 lb ai/acre) on the native plots. Preemergence weed control in all plots consisted of a broadcast application of pendimethalin (1.0 lb ai/acre) plus fluometuron (1.2 lb ai/acre). All appropriate NT, CT and RT treatments were cultivated twice. Additional herbicide applications included broadcast application of pyrithiobac (0.079 lb ai/acre), post-directed application (banded) of prometryn plus MSMA (0.31 and 1.0 lb ai/acre) and a layby application (broadcast) of cyanazine and MSMA (1.1 and 1.65 lb ai/acre).

Based on past work with these cover crops, nitrogen fertilization of the cotton was adjusted to 60 lb N/acre following vetch, 120 lb N/acre following wheat with the other plots receiving 90 lb N/acre. The middle two rows were harvested from each plot 17 October with a spindle picker. On 22 October 1997, following cotton stalk destruction, the wheat and vetch cover crops were planted in the respective plots. The next day, treatments were split for deep tillage using a Paratill, and the appropriate treatments were disked or hipped.

All data were analyzed using the ANOVA or GLM procedures of SAS (SAS Institute, 1989). In order to assess individual treatment factor effects, contrast statements were used following the GLM procedure.

RESULTS

Two days after planting, soil temperature was lower (3 to 5 F) in the furrow (2-in. depth) in the vetch plots compared to the conventional or reduced tillage treatments on both soil types (data not shown). Although the wheat plots were numerically lower than the conventional plots, the differences were not significant. The differences in soil temperature could help to explain some of the observed differences in early growth.

Commerce Silt Loam

Nodes above white flower (NAWF) was affected by some of the treatment factors. With regard to NAWF values recorded on 30 July, the no-till plots had a higher value than conventional or reduced tillage treatments (5.2 vs 4.6 or 4.7), indicating a slight delay in maturity. On the same date there were no differences in NAWF between no-till plots with respect to cultivation (5.2 vs 5.2). Within the no-till plots at this date, cotton in vetch treatments was later maturing than cotton in the plots with a wheat cover crop or native cover (5.4 vs 5.1 or 5.1). This could be partially explained by the lower early soil temperatures, which could have reduced early plant vigor. There was also a difference in NAWF at this date between the plots that were sub-soiled and the plots that were not (5.2 vs 4.9).

Cotton yield was also affected by some treatment factors; contrast statements were again used in order to examine the influence of individual treatment variables. There was no difference in yield between the no-till treatments and the conventional or the reduced till treatments. There was also no difference in yield between the no-till plots that were cultivated and those that were not. With respect to the cover crops, there was no difference between the wheat and the native treatments. However, both the wheat and the native were higher than the vetch treatments (2641 and 2651 vs 2470 lb seedcotton/acre). This could be related to the soil temperature differences seen following planting, which might result in poor early-season plant vigor in the vetch plots. Within the conventional and the reduced till plots, there was no yield difference between the plots that were sub-soiled and those that were not. This is in contrast to the data from 1996, where sub-soiled plots yielded more than non sub-soiled plots. This may indicate that sub-soiling is not necessary every year on this soil type. Within the no-till treatments, sub-soiling actually resulted in a significant decrease in seedcotton yield of 192 lb/acre. As the mechanical action of the sub-soiling results in a reduced and uneven planting bed, some of the decrease in yield may be due to stand establishment. Although there were no statistical differences in stand density, the decrease in yield could be related to stand uniformity, which was much more variable in the no-till plots than were sub-soiled. Overall, the no-till treatment that was not cultivated or sub-soiled and had only native winter cover was numerically the highest yielding treatment in the test at 2880 lb seedcotton/acre (Table 1).

Sharkey Clay

There were no treatment differences in NAWF on this soil type. The lack of a difference in NAWF is most likely related to the lack of plant available water in late July and August (circa 1 in. rainfall). With respect to seedcotton yield, the conventional and the reduced-till treatments resulted in higher yields than the no-till treatments (1935 lb/acre vs 1703 lb/acre). The reduced till plots also resulted in more seedcotton than in the conventional till by 287 lb/acre (Table 2). This confirms previous research and is very similar to what many farmers are already doing on this soil type (stale-seedbed).

ACKNOWLEDGMENT

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Table 1. Treatments used to investigate the effect of conservation tillage practices and winter cover crops on cotton growth and yield on Sharkey clay and Commerce silt loam at the Northeast Research Station near St. Joseph, Louisiana.

	Seedbed Preparation			Cultivation		Sub-soiled		Winter Cover Crop		
Treatment #	no-Till	Fall Bedded	Spring Bedded	Yes	No	Yes	No	Wheat	Hairy Vetch	Native Species
1	**x**			**x**		**x**		**x**		
2	x			x			x	x		
3	x				x	x		x		
4	x				x		x	x		
5	x			x		x			x	
6	x			x			x		x	
7	x				x	x			x	
8	x				x		x		x	
9	x			x		x				x
10	x			x			x			x
11	x				x	x				x
12	x				x		x			x
13		x		x		x				
14		x		x			x			
15			x	x		x				
16			x	x			x			

Table 2. Yield of cotton plants grown in various cover crop and tillage systems on a Commerce silt loam at the Northeast Research Station near St. Joseph, Louisiana, 1997.

Tillage	Cover Crop	Cultivation	Sub-Soil	Seedcotton
				lb/acre
Conventional	None	Yes	Yes	2727
Fall bedded	None	Yes	Yes	2636
No-Till	None	Yes	Yes	2570
No-Till	None	No	Yes	2575
No-Till	Wheat	No	Yes	2560
No-Till	Wheat	Yes	Yes	2520
No-Till	Vetch	No	Yes	2381
No-Till	Vetch	Yes	Yes	2354
Conventional	None	Yes	No	2674
Fall bedded	None	Yes	No	2623
No-Till	None	Yes	No	2580
No-Till	None	No	No	2880
No-Till	Wheat	No	No	2850
No-Till	Wheat	Yes	No	2638
No-Till	Vetch	No	No	2482
No-Till	Vetch	Yes	No	2673
LSD (0.05)				362

Table 3. Yield of cotton plants grown in various conservation tillage systems on a Sharkey clay at the Northeast Research Station near St. Joseph, Louisiana, 1997.

Tillage	Cover Crop	Cultivation	Sub-Soiled	Seedcotton
				lb/acre
Fall bedded	None	Yes	Yes	2097
No-Till	None	No	Yes	1759
No-Till	None	Yes	Yes	1796
Conventional	None	Yes	Yes	1882
No-Till	Vetch	No	Yes	1826
No-Till	Wheat	Yes	Yes	1680
No-Till	Vetch	Yes	Yes	1804
No-Till	Wheat	No	Yes	1698
Fall bedded	None	Yes	No	2053
No-Till	None	No	No	1413
No-Till	None	Yes	No	1615
Conventional	None	Yes	No	1695
No-Till	Vetch	No	No	1836
No-Till	Wheat	Yes	No	1539
No-Till	Vetch	Yes	No	1751
No-Till	Wheat	No	No	1703
LSD (0.05)				413

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ASSESSING NUTRIENT STRATIFICATION WITHIN A LONG-TERM NO-TILLAGE CORN SOIL

D.D. Howard, M.D. Mullen and M.E. Essington[1]

INTRODUCTION

Soil testing is a tool to evaluate the fertility status of a soil. The soil samples collected for this evaluation must represent the field. In most instances, representative soil sample within a production field can be collected based on slope and soil type. However, producers often utilize production practices that create a challenge for obtaining a representative soil sample. Production practices that promote nutrient stratification within a field increase the difficulty of collecting a representative sample.

Banding fertilizers stratifies nutrients in a systematic pattern across the field. Collecting a sample that adequately accounts for banded nutrients without either over- or under-estimating nutrient status presents a challenge. Tyler and Howard (1991) reported random sampling should be utilized on soils having banded fertilizers. Nutrient stratification is also promoted in conservation tillage systems from surface applications of non-mobile nutrients (Howard and Tyler, 1987; Tyler and Howard, 1991; Mullen and Howard, 1992). Conservation tillage promotes nutrient stratification when rows are oriented close to the previous years' rows, allowing nutrient recycling from decaying root biomass (Tyler and Howard, 1991; Mullen and Howard, 1992). After seven years, in-row (IR) nutrient stratification as well as nutrient stratification with depth was evident in a no-till corn soil (Mullen and Howard, 1992). Howard et al. (1997) reported higher extractable K levels for the IR sample position than the BR position on three long-term no-till cotton soils. The objectives of this study were to evaluate the differences in nutrient stratification over time in a long-term no-till corn soil fertilized with several surface broadcast P and K rates. An additional objective was to evaluate residual effects of seven years of in-furrow banding P.

MATERIALS AND METHODS

A field experiment was established at the Milan Experiment Station, Milan, Tennessee, in 1983 and continued through 1996 on a Loring silt loam soil (fine-silty, mixed, thermic, Typic Fragiudalf). A wheat (*Triticum aestivum* L.) cover crop was established in October of each year except in 1988 for the 1989 crop. Corn was planted early to mid April each year in 30-in. rows. Individual plots were four rows wide and 30 ft long.

The experimental design was a randomized complete block with a split-plot arrangement of treatments replicated five times. Main plot treatments were surface broadcast P and K rates with N-P_2O_5-K_2O fertilizer starter combinations as the sub-plots. Main plot P and K rates were: unfertilized check, 50-25, 100-50 and 150-75 lb P_2O_5-K_2O/acre. The two starter treatments selected for sampling were an in-furrow application of 15-30-0 lb N-P_2O_5-K_2O/acre and an unfertilized check. Application of the starter treatments was terminated in 1989. Plots were sampled following the 1989 growing season. Main-plot treatments were terminated following production in 1996, and the same plots were sampled in 1997. Treatment effects on the yield of no-tillage corn from these plots have been reported by Howard and Mullen (1991) and Howard and Tyler (1987).

Nitrogen, applied as UAN (32% N), was injected approximately 2 to 3 in. deep and 4 to 6 in. to the side of the row immediately after planting. The total N rate (UAN + starter) applied per plot was 150 lb/acre. Broadcast P+K treatments were applied mid to late March using concentrated super-phosphate and potassium chloride.

The soil sampling protocol consisted of collecting and combining seven sub-samples from within the row (IR) and between the row (BR) positions in the center of each plot. The IR sample was collected by sampling directly in existing stubble while the BR sample was collected approximately 15 in. from the row. Samples were collected to a 12-in. depth and divided into 0 to 3-, 3 to 6- and 6 to 12-in. depth increments. Mehlich-I-extractable P and K (Mehlich, 1953) were evaluated on the 0 to 3- and 3 to 6-in. depth and averaged for statistical evaluations. Statistical analysis was performed to evaluate the effect of year on extractable P and K by sample position (IR vs BR) from the two original starter treatments (15-30-0 and check) within each main plot. These analyses were conducted utilizing Proc Mixed procedures of the Statistical Analysis System (SAS, 1997). Mean separation was evaluated through a series of pairwise contrasts among all treatments. Probability levels greater than 0.05 were categorized as non-significant.

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RESULTS

Extractable Phosphorus

The level of Mehlich-I-P varied with year of sampling, sampling position (IR vs BR) and starter treatment (Table 1). Extractable P within the 0-P_2O_5 main plot was over twice as high in 1989 as in 1996 (Table 2). Mehlich-I-P was also higher in 1989 than in 1996 for samples collected from the 50-lb P_2O_5 main plot. However, Mehlich-I-P differences between years were not significant for the two higher P_2O_5 fertilizer treatments. In-furrow application of 30 lb P_2O_5/acre to the starter plot resulted in higher Mehlich-I-P from the 0-, 50- and 100-lb P_2O_5 main plots compared with Mehlich-I-P from the check plot. Broadcasting 150 P_2O_5/acre eliminated Mehlich-I-P differences due to starter applications. Extractable P was higher in the IR position relative to the BR position in the 0- and 50-lb P_2O_5/acre main plots, but the reverse occurred in the 100- and 150-lb P_2O_5 main plots. The year-by-starter-by-position interaction affected extractable P within each P_2O_5 main plot (Table 1). Mehlich-I-extractable P within the unfertilized main plot (0-lb P_2O_5 rate) was greater in the 1989 IR position of the starter plot compared with the other treatments (Table 3). In-furrow applications of 30 lb P_2O_5/acre clearly impacted extractable P. In 1996, differences in Mehlich-I-P due to sampling position were not detected. Seven years after terminating the in-furrow starter applications, extractable P in the IR position had decreased from 30 to 7 lb/acre, a change from a high (H) to a low (L) soil test level. There is a possibility that the in-furrow-applied P_2O_5 was not intersected in 1996 sampling, but planting within the same 10-ft plot should have allowed sampling of one of the seven in-furrow P_2O_5 applications. This observation suggests that the soil has high P buffering capacity.

As expected, broadcasting 50 lb P_2O_5/acre resulted in greater Mehlich-I-P relative to the unfertilized main plot (Table 2). Application of the 50 lb P_2O_5 rate to a main plot changed the pattern of Mehlich-I-P based on sampling protocol (Table 3). As was observed for the 0-lb P_2O_5 main plot, extractable P from the 1989 IR starter sample was greater than that extracted from the other treatments. By 1996, Mehlich-I-P in the BR starter position was greater than that of either sampling positions within the check. Extractable P within this main plot ranged from a high of 68 lb/acre to a low of 15 lb/acre.

Once again, the extractable P pattern changed when sampling a higher P_2O_5 rate (100 lb). The in-furrow application of 30 lb P_2O_5 was detected in the 1989 IR starter sample (Table 3). The extractable P in the IR position had not changed by 1996 (74 and 63 lb). However, extractable P in the BR position had increased by 1996. Extractable P from the starter BR position was higher in 1996 than the extractable P from either sample position within the check plot. Broadcasting 100 lb P_2O_5/acre for 14 years increased Mehlich-I-P levels well into the H soil test rating.

Broadcasting 150 lb P_2O_5/acre over the 14 years once again changed the pattern of extractable P in this soil when compared with the other main plot fertilization rates (Table 3). The 1989 IR starter position was higher in extractable P than the BR position but the reverse was observed in the check sample. By 1996, extractable P was unaffected by sampling position of the starter. As was observed in 1989, extractable P from the 1996 BR position in the check was higher than the IR position. Differences in extractable P between the 1989 and 1996 samples due to sample positions (IR vs BR) were similar, 29 and 31 lb P/acre, respectively.

These data indicate that Mehlich-I-P was vertically stratified within a long-term no-tillage corn soil. Stratification was dependent on fertilization applied either as surface broadcast rates or in-furrow starter treatments. Nutrient stratification would affect fertilizer recommendations on those soils having low fertilizer applications for M or L Mehlich-I-P soil test levels.

Extractable Potassium

Mehlich-I-extractable K was affected by sampling time, position (IR vs BR) and starters within the 0 and 50 lb K_2O/A main plots (Table 1). Extractable K within the 0 and 25 lb K_2O fertilized main plots was lower in 1996, indicating depletion by crop removal (Table 2). The check plot had higher extractable K than the starter within the 0-lb K_2O main plot, but the reverse was observed for the 50-lb K_2O/acre main plot. This is interesting since K was not in-furrow applied as a starter fertilizer. Sampling the IR position resulted in higher extractable K relative to BR sampling of main plots.

Mehlich-I-extractable K within the 50- and 75-lb K_2O main plots was affected by a year-by-starter-by-sample position interaction (Table 1). Extractable K of the 1989 starter plot within the 50-lb K_2O main plot was unaffected by sample position (Table 3). But extractable K was greater in the check IR position compared with the BR sample. The level of extractable K in the 1989 IR or BR positions was the same for both starter plots. The levels were the same for the BR position within the starter and check plots. By 1996, IR-extractable K was greater in both starter treatments compared with the BR position sample, but 1996 extractable K in the starter IR position was higher than the check IR position. In 1996, extractable K from the IR starter position (197 lb K/acre) would be classified as high while the BR sampling would be medium (113 lb K/acre). Soil samples collected from either IR or BR positions would be assigned a soil test rating of M. However, stratification within the starter plot had reduced extractable K in the BR position from 142 to 107 lb/acre, which is approaching a L soil test rating.

Broadcasting 75 lb K_2O resulted in significant differences in extractable K with sampling position, but differences between starter plots and years were not detected (Table 2). Extractable K from the IR sampled position was greater than the extractable K from the BR positions (Table 3). Vertical stratification of K was occurring in the long-term no-tillage corn soil. Stratification was greater as the rate surface-applied fertilizer increased. The soil K test level from the IR position would be classified as H or M for the BR position. Soil test fertilizer recommendations would vary depending on the position sampled.

CONCLUSIONS

Vertical stratification of Mehlich-I-extractable P and K has occurred in a long-term no-tillage corn soil. The amount of stratification was dependent on the broadcast rates of P_2O_5 and K_2O as well as previous starter applications. The effect of P starters was not detected in samples collected seven years after starter termination. Extractable P tended to be higher in the BR sample position relative to the IR sample position while the reverse was true for extractable K. A sampling protocol other than a random sampling may affect the extracted levels of both nutrients, which may affect fertilizer recommendations.

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Table 1. Type III F-values from statistical analysis of Mehlich-I-extractable phosphorus and potassium from a long-term no-tillage soil in corn production.

		Extractable P				Extractable K			
		Broadcast P rates				Broadcast K rates			
Item	df	0	50	100	150	0	25	50	75
Year (Y)	1	22.7**	79.6**	0.8	2.9	29.6**	8.4*	6.4	1.2
Error a	4								
Starter (S)	1	19.3**	106.7**	25.5**	3.4	13.9**	1.1	7.7*	0.2
S*Y	1	10.5*	39.1***	0.0	1.5	1.8	0.2	4.3	0.3
Error b	8								
Position (P)	1	14.6**	45.5***	7.4*	9.4**	89.3***	49.0***	83.2***	116.5***
P*Y	1	18.6***	94.0***	7.5**	5.8*	0.0	11.1**	29.3***	3.2
S*P	1	17.2**	68.7***	0.2	15.3***	3.0	0.0	1.2	0.0
S*P*Y	1	23.1***	78.4***	5.0*	4.6*	1.1	1.0	6.1*	4.5*
Error c	16								

*, **, *** Significant at the 0.05, 0.01 and 0.001 probability level, respectively.

Table 2. Mehlich-I-extractable phosphorus (P) and potassium (K) from a long-term corn experiment as affected by year, starter applications and sampling position.

	Broadcast P_2O_5 rates (lb/acre)				Broadcast K_2O rates (lb/acre)			
	0	50	100	150	0	25	50	75
YEAR	--------------------------lb extractable P-------------------------				-------------------------lb extractable K---------------------------			
1989	14 A[1]	33 A	62 A	94 A	130 A	147 A	156 A	181 A
1996	6 B	20 B	58 A	102 A	103 B	129 B	144 A	170 A
STARTER								
Starter	14 A	34 A	72 A	103 A	109 B	140 A	156 A	174 A
Check	7 B	19 B	49 B	93 A	123 A	136 B	143 B	177 A
POSITION								
In-Row	13 A	31 A	56 B	92 B	128 A	151 A	171 A	208 A
Between-Row	8 B	22 B	65 A	105 A	105 B	125 B	129 B	143 B

[1]Within a column of each P or K rate, means followed by the same letter are not significantly different at $\alpha = 0.05$.

Table 3. Effect of broadcast phosphorus and potassium rates, starter applications, year of sampling and sampling position on Mehlich-I-extractable phosphorus and potassium.

In-furrow treatment	Sample Position	Year	Broadcast P_2O_5 and K_2O rates 0-0	50-25	100-50	150-75
			--------lb extractable P/acre--------			
Starter	IR	1989	30 A*	68 A	74 AB	113 AB
	BR	1989	9 B	21 BC	65 BC	90 CD
Check	IR	1989	7 B	20 BC	43 D	72 D
	BR	1989	8 B	21 BC	51 CD	101 ABC
Starter	IR	1996	7 B	20 BC	63 BC	96 BC
	BR	1996	8 B	25 B	85 A	112 AB
Check	IR	1996	6 B	15 C	45 D	85 CD
	BR	1996	5 B	19 C	56 CD	116 A
			--------lb extractable K/acre--------			
Starter	IR	1989	136 A	154 A	163 B	198 A
	BR	1989	115 A	144 A	152 BC	157 B
Check	IR	1989	146 A	155 A	166 B	219 A
	BR	1989	122 A	138 A	142 C	151 B
Starter	IR	1996	102 A	153 A	197 A	214 A
	BR	1996	86 A	110 A	113 D	127 B
Check	IR	1996	127 A	143 A	158 BC	201 A
	BR	1996	98 A	108 A	107 D	138 B

* Within a column for each K rate, means of each extractable nutrient followed by the same letter are not significantly different at $\alpha = 0.05$.

MEASURING SOIL QUALITY ON THE 'OLD ROTATION'

Michael D. Hubbs, D.W. Reeves and Charles C. Mitchell Jr.[1]

ABSTRACT

Low residue-producing crops such as cotton (*Gossypium hirsutum* L.), especially when grown in monoculture, are detrimental to soil quality. Cover crops, crop rotations with legumes and high-residue crops can improve soil quality. The 'Old Rotation' (1896) is the oldest continuous cotton experiment in the world and includes rotations and winter legume cover crops in cotton production systems. There are six treatments in the 'Old Rotation': a three-year rotation of cotton and grain crops plus a winter legume cover crop; two fertilizer treatments (with and without N fertilizer) imposed on a two-year rotation of cotton and a grain crop plus a winter legume cover crop; and three continuous cotton cropping systems (with N fertilizer, without N or N supplied from a winter legume cover crop). Because of the uniqueness of 'Old Rotation' and the current interest in soil quality, the specific objectives of this study were: 1) to determine the effects of rotations on soil quality after 100 years; 2) to evaluate the *USDA Soil Quality Kit* and compare results with standard procedures for selected indicators; and 3) to develop a baseline of soil quality indicators to monitor change. After 100 years, soil quality was better for the three-year rotation and the two-year rotation plus N due to higher soil C (1.3 and 1.1%, respectively, compared to a mean of 0.8% for others). The three-year rotation had higher percentage water stable aggregates (64% compared to a range of 34 to 53% for other treatments). Cation exchange capacity was highest for the three-year rotation and the two-year rotation (5.5 and 5.4 $cmol_c/kg$, respectively, compared to a mean of 4.4 $cmol_c/kg$ for other treatments). Soil strength was lowest (six bars) for the three-year rotation while continuous cotton without a cover crop or N had the highest soil strength in the top 4 in. of the plow layer. Kit measurements had higher variability relative to standard procedures. Soil moisture was greater at the time Kit measurements were taken and fewer samples were used, which may explain increased variability. The Kit can be used to evaluate trends and comparisons but should not be used in place of standard procedures for research. Information from this study will set a baseline for soil quality indicators for the 'Old Rotation', and future studies will measure the differences in soil quality as a result of the conversion to conservation tillage in 1997.

INTRODUCTION

The 'Old Rotation' experiment at Auburn University has been in continuous production since 1896 (Mitchell et al., 1996), and the purpose of this study was to show that the use of crop rotations and legume cover crops could sustain cotton and corn yields. In the spring of 1997, after 100 year of conventional tillage, the 'Old Rotation' was converted to conservation tillage. We were interested in the effects of long-term legume cover crops, crop rotations and N fertilizer on soil quality. We also needed a baseline value for soil quality in order to monitor change as the 'Old Rotation' was converted to conservation tillage.

Soil quality is "the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Karlen et al., 1997). Soil quality cannot be measured directly but must be inferred by its attributes or indicators (Seybold et al., 1998). Karlen et al. (1997) suggested using indicators such as organic matter, infiltration, aggregation, pH, bulk density, electrical conductivity and available nutrients to monitor soil quality.

Because of the uniqueness of the long-term rotations in the 'Old Rotation' and because of the current interest in soil quality, we wanted to measure the effects of these long-term treatments on soil quality. The specific objectives of this study were: 1) to determine the effects of rotations on soil quality indicators after 100 years; 2) to evaluate the *USDA Soil Quality Kit* (Liebig et al., 1996) and compare results with standard procedures for selected indicators; and 3) to develop a baseline of soil quality indicators in order to compare future effects of conservation tillage, cover crops and crop rotations on soil quality.

MATERIALS AND METHODS

The 'Old Rotation' consists of 13 plots (Mitchell et al., 1996). Each plot is 21.5 ft by 136.1 ft and is separated by 3-ft alleys. Treatments in the 'Old Rotation' have evolved into six rotations (Table 1). The soil at the site of the rotation is currently identified as Pacolet fine sandy loam (clayey, kaolinitic, thermic Typic Hapludults), a typical Piedmont soil. The soil has a Coastal Plain cap similar to

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a Marvyn loamy sand (fine-loamy, siliceous, thermic Typic Kanhapludults). The site is on a gently rolling slope (~3 %). Confusion for the soil identification is due to Auburn being located at the junction of the two physiographic regions with the upper part of the site (plot #1) more characteristic of a Coastal Plain soil and the lower portion (plot #13) more characteristic of a Piedmont soil (Mitchell et al., 1996).

Standard Procedures

Nine standard tests were used to measure selected soil quality indicators. Soil strength was measured using a recording cone penetrometer with 10 insertions per plot, beginning at 0.6 in. and recording a reading every 0.6 in. to 24 in. deep. Bulk density was determined from five undisturbed cores per plot at zero to 3 in. using the method of Blake and Hartge (1986). Gravimetric soil water content was measured by taking five undisturbed cores from each plot at the 0- to 3-in. depth (Gardner, 1986). Hydraulic conductivity (K_{sat}) was determined (Klute and Dirkson, 1986) from five undisturbed cores per plot at three different depths (0 to 3, 3 to 6 and 6 to 8 in.) for a total of 15 samples per plot. Soil samples for nutrient determination were taken at three depths (0 to 1.5, 1.5 to 6 and 6 to 10 in.) with composite samples from 10 random sites per plot. Soil nutrients were extracted using Mehlich-I and analyzed (Odom and Kone, 1997) using an inductively-coupled-plasma (ICP) analyzer. Elements determined were Ca, K, Mg, P, Cu, Fe, Mn, Zn, B, Mo, Al, Co and Na. Cation exchange capacity (CEC) (Rhoades, 1986) and pH were also determined (Tan, 1996). Samples for soil C and N were taken from five locations per plot to form three composite samples by depth (0 to 1.5, 1.5 to 6 and 6 to 10 in.) The samples were prepared by fine grinding on a conveyor-belt apparatus to reduce sample variability (Kelley, 1994). Duplicate samples were analyzed for carbon and nitrogen by a combustion technique. Percent water stable aggregates were determined (Kemper and Rosenau, 1986) from samples taken from five locations per plot forming three composite samples for depths of 0 to 1.5, 1.5 to 6 and 6 to 10 in. During wet sieving, two sub-samples were analyzed from each sample for a total of six samples per plot.

The Soil Quality Kit Procedures

The *USDA Soil Quality Kit* (Kit) was used to measure seven soil quality indicators. Samples for all indicators were taken at three random positions per plot to the 3-in. depth. Infiltration rate was measured using an aluminum ring 6 in. in diameter and 5 in. in length. The ring was driven into the ground to a depth of 3 in. Water (1 in.) was poured in the ring; the time it takes to infiltrate is the determined infiltration rate (in./min). A lid with a rubber septa was placed on top of the ring for 30 min to accumulate CO_2 respired by soil organisms and plant roots. Air in the covered ring was sampled with a syringe and passed through a Drager 0.1 % CO_2 tube and CO_2 determined colorimetrically. Bulk density and soil water content were measured by inserting a 3-in.-diameter cylinder into the ground. Calculations are similar to standard tests. Soil water content samples for the standard method were collected during a period of dry weather prior to planting (April 1997) while the *USDA Soil Quality Kit*'s sampling was done in July after several rains. Soil pH and electrical conductivity (EC) were measured using pocket meters in a 1:1 soil to water ratio. Soil nitrate content was determined by dipping nitrate test strips in a filtered extract. The test strip color was compared to a standard color chart, indicating concentrations of nitrate.

Statistical Analysis

Data were analyzed using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS Institute, 1988). Least-squares means statements were used for means separation. Pearson product-moment correlation among measured variables and methods were calculated using the CORR procedure of SAS (SAS Institute, 1988).

RESULTS AND DISCUSSION

The standard method for determining soil water content showed significant differences among treatments. The three-year rotation plus legume cover crop (treatment 1) had the highest average water content while the continuous cotton treatments (treatments 2 and 3) had the lowest soil water content (Table 2). Sampling for soil water with the Kit at a later date showed no significant differences among treatments due to a higher variance in the data. Also, we took five sub-samples during sampling for the standard procedures and only three sub-samples with the Kit. Fewer samples taken with the Kit likely contributed to more variability. There was good correlation between the two methods (r = 0.77), but the Kit's method had a much higher coefficient of variation (c.v.), 32% compared to 8% for the standard method.

There were significant differences in K_{sat} (standard procedure) among treatments but not by depth. The c.v. was high (62%). Infiltration measurements taken with the Kit showed a trend for differences between the three-year rotation and other treatments ($P \leq 0.14$); however, the c.v. was 95%.

Soil C was highest for the three-year rotation (treatment 1) and lowest for continuous cotton without a legume cover crop or N (treatment 2) (Table 3). Respiration measurements (Kit) showed no differences among treatments. However, there was good correlation between laboratory determination of total C and respiration as measured by the Kit (r = 0.75). The Kit's method showed more variation with a c.v. of 33% for respiration compared to 10% for soil C determination using standard procedures. Generally, soil respiration was commensurate with soil C concentrations. The continuous cotton plus N (treatment 3) and two-year rotation (treatment 4) were exceptions.

Electrical conductivity measured by the Kit showed significant differences among treatments. Treatment 3, continuous cotton with 120 lb of N (plot #13) had a higher EC (0.67 dS/m) than other treatments (range from 0.10 to 0.20 dS/m). This may be the result of accumulation of Na from fertilizer treatments of sodium nitrate prior to Word War II. Plot # 13 is at the slope end of the site and has a higher clay content (25%) (Mitchell et al., 1996) than most of the other plots (< 20%), which may contribute to greater retention of salts. There were no differences among other treatments in EC.

Cation exchange ranged from 3.1 $cmol_c$/kg for continuous cotton without legume or N (treatment 2) to 5.5 $cmol_c$/kg for the three-year rotation (Table 4). Increases in CEC were due to more intense rotations, the use of legume cover crops and N fertilization. These results are similar to those for soil carbon (Table 4). Treatment 3 was relatively higher (5.6 $cmol_c$/kg) due to higher clay content compared to other plots.

The percentage water stable aggregates ranged from 35% in cotton without legume but N fertilizer (treatment 3) to 64% in the three-year rotation with legume cover crop (treatment 1). Aggregate stability was increased by rotation, cover crop use and N fertilizer but was also affected by clay content (data not shown).

The ICP analysis showed significant differences by treatment and depth for extractable P and by depth only for extractable K. Phosphorus levels were lowest for the two-year rotation without N (treatment 6) and three-year rotation (41 and 45 mg/kg, respectively) while continuous cotton without a cover crop and N was highest (99 mg/kg). Rotation treatments have had little effect on other nutrients due to the use of conventional tillage for the past 100 years, which has evenly distributed nutrients through the plow layer. Differences in P and K were limited to the upper 6 in. of the plow layer and were due to fertilizer applications, reduced plant removal of nutrients in less productive rotations and mixing of soil in the plow layer due to tillage. The elemental analysis data will serve as a baseline to monitor changes in nutrient stratification caused by conservation tillage in the future.

There were significant differences in soil strength among treatments to the 4-in. depth (Fig. 1). The two continuous cotton treatments without cover crops (treatment 2 and 3) had the highest mean ranges. There was a strong trend for differences to the 10-in. depth ($P \leq 0.25$). With the exception of continuous cotton (treatment 2), there was considerable compaction below the 10-in. depth. Continuous cotton (treatment 2) shows reduced soil strength at the 10-in. depth, possibly due to high variability in the data (~55 % c.v.) or inherent differences in the soil profile between it and other plots. The variability could be the result of the 'Old Rotation' plots being located in a transition zone, including both Piedmont and Coastal Plain soil types.

CONCLUSIONS

After 100 year of using a legume cover crop and crop rotations with high residue crops like corn and small grains, soil quality is better for the three-year rotation plus a winter legume cover crop (treatment 1) due to higher soil carbon, more water stable aggregates, higher CEC, reduced soil strength at the surface and higher soil water retention. In contrast, continuous cotton without a legume cover crop had lower soil carbon, lower water stable aggregates, lower soil water retention and greater soil strength down to 5 in. Nitrogen fertilizer and/or a legume cover crop within continuous cotton rotations contributed to more residues and greater soil carbon accumulation over past 100 years. The same can be said for the two-year rotations that included a high-residue crop (corn) plus a legume cover crop with or without nitrogen. With the exception of P, rotation treatments had little effect on extractable plant nutrients due to the use of conventional tillage for the past 100 years. However, these data will be used as a baseline to monitor future changes in nutrient stratification caused by conservation tillage.

The USDA Soil Quality Kit is designed for semi-quantitative assessments and for education on soil quality. The Kit can be useful for a conservationist or farmer to compare management practices to assess trends in soil quality but should not be used for research. Soil carbon data will be beneficial to interpret Kit respiration readings. The Kit had higher variation (c.v.) than comparable standard procedures. This may have been due to use of fewer samples for kit measurements than for standard procedures. More intensive sampling and incorporating data from standard tests can improve the reliability and usefulness of the Kit.

The benefits of crop rotations and cover crops should be enhanced by the addition of conservation tillage as a management practice in the 'Old Rotation'. The impact of conservation tillage on soil quality in the 'Old Rotation' can be monitored in the future using these established baseline values.

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Table 1. The 'Old Rotation' treatments.

Treatment	Plots	Rotations	N management
1	10, 11 and 12	Three-year rotation of cotton fb[1] legume cover crop (*Trifolium incarnatum* L.) fb corn (*Zea mays* L.) fb wheat (*Triticum aestivum* L.) or rye (*Secale cereale* L.) for grain fb soybean [*Glycine max* (L.) Merr.]	60 lb/acre applied to wheat or rye
2	1 and 6	Continuous cotton without a cover crop	No N
3	13	Continuous cotton + N without a cover crop	120 lb/acre applied to cotton
4	2, 3 and 8	Continuous cotton + legume cover crop	No N
5	4 and 7	Two-year rotation of cotton-corn +legume cover crop	No N
6	5 and 9	Two-year rotation of cotton-corn + legume cover crop	120 lb/acre applied to cotton

[1]fb = followed by.

Table 2. Comparisons of some soil quality indicators determined from standard tests vs. the *USDA Soil Quality Kit.* Means followed by the same letter are not significantly different at P ≤ 0.10.

	Bulk Density		Soil Water		K_{sat}	
Treatments	Standard	Kit	Standard	Kit	Kit	Standard
	-----------g/cm³-----------		-------------%-------------		----------in./min----------	
Three-year rot. + legume cover crop	1.65	1.38	11.47a	19.75a	1.22	0.09bc
Cont. cotton with no legume	1.66	1.44	7.69c	9.98b	0.37	0.15a
Cont. cotton + 120 lb N/acre	1.73	1.45	9.40bc	12.27ab	0.04	0.03c
Cont. cotton + legume cover crop	1.66	1.49	9.47b	15.12ab	0.43	0.09bc
Two-year rot. + legume cover crop	1.68	1.42	10.11ab	14.87ab	0.57	0.08c
Two-year rot. + legume cover crop + 120 lb N/acre	1.62	1.40	11.67a	14.11ab	0.33	0.15a

Table 3. Comparisons of some soil quality indicators determined from standard tests vs. the *USDA Soil Quality Kit.* Means followed by the same letter are not significantly different at P ≤ 0.10.

Treatments	pH (standard)	pH (Kit)	Respiration (Kit)	Total C (standard)	Total N (standard)	Nitrates (Kit)
			lb/C/day	%	%	ppm
Three-year rot. + legume cover crop	5.92c	5.83b	60.16a	1.27a	0.05ab	4.78b
Continuous cotton with no legume	7.16a	7.10a	22.07b	0.50d	0.02c	1.67b
Continuous cotton + 120 lb N/acre	6.07bc	4.67c	36.28ab	0.87c	0.04abc	50.00a
Continuous cotton + legume cover crop	6.22b	5.93b	43.91ab	0.84c	0.04ab	6.11b
Two-year rotation + legume cover crop	6.32b	5.84b	60.42a	0.85c	0.05ab	2.83b
Two-year rotation + legume cover crop + 120 lb N/acre	5.52d	5.05c	44.73ab	1.09b	0.06a	10.34b

Table 4. Comparisons of CEC and water stable aggregates % (WSA) determined from standard tests. Means followed by the same letter are not significantly different at P ≤ 0.10.

Treatments	CEC	WSA
	$cmol_c$/kg	%
Three-year rotation + legume cover crop	5.5a	64.1a
Continuous cotton /no legume	3.1c	49.8b
Continuous cotton + 120 lb N/acre	5.6a	34.7c
Continuous cotton + legume cover crop	4.3b	52.2b
Two-year rotation + legume cover crop	4.6b	53.2b
Two-year rotation + legume cover crop + 120 lb N/acre	5.4a	48.9b

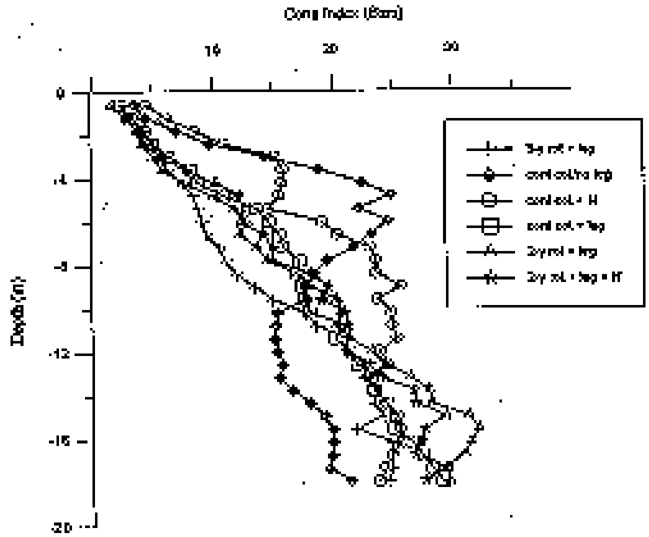

Fig. 1. Soil strength as influenced by treatment.

NITROGEN RATES AND COVER CROPS FOR NO-TILL COTTON IN THE MISSISSIPPI BROWN LOAM

J.R. Johnson and J.R. Saunders[1]

INTRODUCTION

A soil resource area east of the Mississippi Delta that runs the entire length of the state and varies in width from 50 to 125 miles is referred to as the Brown Loam soils area of Mississippi. Soils of this area are some of the most erosive soils in the nation. Soils of the Brown Loam are loess soils and have little or no cohesion. When wet the soil particles appear to disperse in water as soils having no structure, making for easy soil erosion. Low organic matter makes these soils susceptible to crusting and sealing following spring rains, which creates conditions conducive to water erosion. In addition, many of the soils have slopes exceeding 10%, which further contributes to erosion. In order to meet the requirements of the 1985 Farm Bill, no-till and minimum tilled practices had to be adopted with the use of cover crops and buffer strips if row crops were to be grown on the Brown Loam. Reducing tillage and growing a cover crop increased surface residue, which helped decrease erosion along with supplying or depleting nitrogen from the soil, depending on type of cover crop.

Wheat, native weeds and grasses deplete nitrogen from the soil whereas clover and vetch add nitrogen to the soil. It was estimated by Stevens et al. (1993) that a wheat cover crop will require 30 additional units of nitrogen during the growing season to compensate for the nitrogen the microbes need to decompose the wheat residue. Brown et al. (1985) estimated that a clover cover crop will add between 30 and 45 lb of nitrogen to the soil and a vetch cover crop will add between 45 and 60 lb of nitrogen to the soil.

A study was started at the North Mississippi Branch Experiment Station in Holly Springs, Mississippi, to determine the nitrogen requirements of no-till grown cotton using wheat, native cover and vetch as the winter cover crops. This information would be useful in helping producers select cover crops and managing no-till grown cotton.

MATERIALS AND METHODS

In 1996 and 1997 nitrogen studies were conducted on fields that were in cotton production the previous year. After cotton harvest the stalks were cut 19 October 1995 using a rotary cutter leaving a plant stubble of approximately 8 in. After stalk shredding, wheat and vetch were planted no-till in the cotton stubble 20 October with a Tye grain and small seed drill in a randomized compete block. Wheat was seeded at 90 lb of seed/acre and vetch was seeded at 45 lb/acre. In the spring of 1996 the wheat, vetch and native cover had Roundup (glyphosate) sprayed over the top at a rate of 2.0 lb ai/acre 8 April l996. A second burndown was made using Gramoxone (paraquat) at 0.5 lb ai/acre 27 April 1996.

The same cover crop management techniques were used in the 1996-97 cover crops except for dates of planting and burndown. In 1996 the cotton stalks were cut 4 November, and cover crops were seeded 5 November. First burndown treatment was sprayed 24 April 1997, and second burndown was sprayed 19 May 1997. A split block design was used with cover crops planted in a randomized complete block and nitrogen levels as subplots randomized within each block. Each plot consisted of eight rows 38 in. wide and 50 ft long. All treatments were replicated four times.

A blend of dry phosphorus and potassium fertilizer was broadcast according to soil test recommendations 27 April 1996 and 7 April 1997 across the entire plot area. All cotton planting was done using a John Deere Max-Emerge Model 7100 planter equipped with bubble coulters to cut through the residue in the no-till systems. Cotton was planted 27 April 1996 and 19 May 1997. At planting Temik (aldicarb) was applied in the drill at 0.75 lb ai/acre. Terrachlor Super X (pentachloronitrobenzene) was applied at planting in the seed drill at the rate of 2.0 lb ai/acre. Cotoran (fluometuron) and Dual (metolachlor) were sprayed broadcast at a rate of 0.75 and 1.0 lb ai/acre. Spray solution was applied at the rate of 18 gallons/acre. Staple (pyrithiobac sodium) was sprayed broadcast over the entire study when the cotton had reached the three- and four-leaf stage. Select (clethodim) at 0.3 lb ai/acre was broadcast over the entire study when the cotton was near first bloom. A lay-by herbicide mixture of Bladex (cyanazine) at 1.0 lb ai/acre and MSMA at 0.75 ai/acre was directed under the cotton and in the middles at approximately eight weeks after planting. Insect control was according to standard recommended practices and thresholds.

Nitrogen fertilizer rates of 0, 30, 60, 90, 120 and 150 lb/acre were evaluated to determine the optimum nitrogen

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rates for each cover crop. Nitrogen was applied using a tractor-mounted Gandy calibrated for each N rate. Ammonium nitrate (34% N) was the source of nitrogen. Nitrogen was placed approximately 1 ft from the drill and 2 in. below the surface. All nitrogen was applied after emergence and before matchhead-sized squares were present.

Chlorophyll fluorescence measurements were made using a Minolta Spad 502 hand-held fluorescent meter on the leaves of 20 plants selected at random within each plot and averaged across the plants for a single plot reading. Leaf readings were taken on the fifth expanded leaf below the terminal of the plant. Chlorophyll fluorescence measurements were made at first bloom, two weeks after first bloom and four weeks after first bloom.

Twenty petioles were collected from the same leaf from which the chlorophyll fluorescence reading was taken, of each plant, of each plot, of each treatment and each replicate for evaluation of nitrate-N status using a Minolta hand-held nitrogen meter. Sampling of petioles was made at first bloom and four weeks after first bloom. Petioles were collected from the fifth fully expanded leaf on the main stem below the plant terminal. Petioles were frozen immediately after collection. Analysis was conducted in an air-conditioned laboratory 24 hours after collection. It was hoped that this would eliminate a variation in the meter reading from exposure to sunlight or temperature variation. Petioles were processed by thawing them under an infrared light for 5 min before the stems were cut into lengths of approximately 1 in. Petiole sap was extracted by placing the cut petiole stems into a garlic press and squeezing out the petiole sap. Approximately 1 ml of sap was squeezed into a test tube from a composite of the 20 petioles of each plot. Two or three drops of sap of each test tube were placed on the calibrated meters. Meter calibration was checked by running a standard at the start of each test period and after every 20 samples.

A defoliant was sprayed over the crop when more than 75% of the bolls were open. Yields were determined by harvesting the two center rows of each eight-row plot. Yields are reported in pounds of seedcotton per acre.

RESULTS AND DISCUSSION

Cotton stands were excellent for both years in all plots. Rainfall was above average in early season of both years. However, the plants suffered severe drought in mid and late season of 1996. Heat units in DD 60's were near normal for northern Mississippi in both years. In 1997, the DD 60's accumulation was extremely slow during the first of the growing season but gained momentum as the season progressed to end with normal DD 60's.

Chlorophyll fluorescence measurements and petiole nitrate-N sap analyses for 1996 are not reported since the techniques that were used varied in accumulating averages for fluorescense and extracting sap from petioles. It was not until the 1997 growing season that a uniform process of collecting, processing and analyzing the petiole sap and chlorophyll fluorescence was worked out.

Chlorophyll fluorescence measurements made in this study in 1997 were not very sensitive to levels of fertilizer nitrogen above 30 lb/acre at the second and fourth week of bloom (Table 1). This was in agreement with studies by Radin et al. (1985) conducted in Arizona on irrigated cotton where leaf conductance was not affected by nitrogen level except in severe N deficits. Only the 90-lb level fluorescence at the first week of bloom had a lower reading than any level above 30 lb, and no logical explanation exists for this low reading. Chlorophyll fluorescence tended to be higher at two weeks and four weeks after bloom for all N levels than at the onset of fruiting. Chlorophyll measurements for cover crops were non-significant at each blooming period (Table 2).

Average petiole nitrate-N sap measurements were significantly lower at first and fourth week of bloom for the 0 N level across all cover crops (Table 3). At first week of bloom, the petiole sap measurement was higher for the 90-lb level than any of the other levels above 30 lb contrasted to fluorescence measurements where the 90-lb level was lower than other levels above 30 lb. Fourth week of bloom, petiole nitrate-N sap levels were non-significant for the N levels of 30 to 150 lb/acre. Petiole sap measurements dropped 53%, 18%, 20%, 31%, 18% and 18% between the first week of bloom and the fourth week of bloom for the 0-, 30-, 60-, 90-, 120- and 150-lb/acre level, respectively. Petiole sap measurements for the wheat and vetch were higher than the native cover crop at first week and fourth week of bloom (Table 4). Petiole sap measurements dropped 12%, 16% and 20% between the first and fourth week of bloom for the wheat, native and vetch cover crops, respectively.

The 1996 yield data were extremely hard to interpret because no pattern was established for nitrogen rates (Table 5). Yields followed the same pattern as the first, second and fourth week of bloom in fluorescence readings in 1997; no difference was noted between cover crop yields. Soil samples were taken after the growing season, and analysis, incomplete at this time, should reflect residual N levels. The 150-lb N/acre level was the only level that yielded higher than the 0-lb N/acre level in 1997. The results presented here are disappointing when expecting a yield response from N levels between the 0 and 150 lb N/acre. Yet this is why the Brown Loam area was an important cotton growing region before commercial fertilizer and has always been an important growing region of Mississippi. The area appears to have a natural fertility of N for cotton. Arnold et al. (unpublished data), working with cotton fertility and N levels for many years at the North Mississippi Branch Station, were able to produce 200 lb lint/acre without the addition of N, P and K for 15 consecutive years.

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Table 1. Chlorophyll fluorescence reading for nitrogen rates averaged across cover crops taken with a hand-held Minolta Spad 502 meter, 1997.

	Blooming Period		
lb N/acre	1st week	2nd week	4th week
0	43.65	42.26	42.69
30	48.81	49.32	52.00
60	49.62	50.90	54.33
90	44.94	49.74	52.70
120	45.98	48.71	54.35
150	51.41	50.35	54.44
LSD (0.05)	1.58	1.85	1.67
CV	3.7	4.2	3.6

Table 2. Chlorophyll fluorescence reading for cover crops averaged across nitrogen rates taken with a hand-held Minolta Spad-502 meter, 1997.

	Blooming Period		
Cover Crop	1st week	2nd week	4th week
Wheat	47.95	48.79	52.42
Native	47.64	49.34	51.48
Vetch	46.60	47.50	51.35
LSD (0.05)	ns	ns	ns
CV	4.1	4.1	5.1

Table 3. Petiole sap analysis of N rates averaged across cover crops using a Minolta hand-held nitrate-N meter (data in ppm x 100), 1997.

	Blooming Period	
N rates (lb N/acre)	1st week	4th week
0	55.00	25.75
30	73.25	59.67
60	77.33	61.83
90	85.42	59.33
120	74.42	60.50
150	74.00	60.59
LSD (0.05)	10.10	11.72
CV	17.10	23.60

Table 4. Petiole sap analysis of cover crops averaged across nitrogen rates using a Minolta hand-held nitrate-N meter (data in ppm x 100), 1997.

	Blooming Period	
Cover Crops	1st week	4th week
Wheat	71.33	62.50
Native	57.33	48.13
Vetch	66.33	53.21
LSD (0.05)	5.45	5.65
CV	11.60	14.70

Table 5. Seed cotton yields of wheat, native cover and vetch cover crops using 0, 30, 60, 90, 120, 150 lb nitrogen/acre, 1996 and 1997.

	Year		
N rates (lb N/acre)	1996	1997	Average
Wheat			
0	620	2822	1721
30	881	2500	1690
60	641	2824	1732
90	1069	3935	2502
120	708	3564	2163
150	968	3390	2179
Native			
0	628	2860	1724
30	814	2697	1756
60	908	3934	2421
90	1215	3465	2340
120	767	3663	2215
150	1301	3762	2531
Vetch			
0	795	2994	1894
30	1014	3118	1894
60	802	3120	1961
90	1088	2275	1681
120	924	2673	1798
150	939	3560	2249
LSD (0.05)	158	304	
CV	16	15	

TILLAGE STUDIES ON COTTON

T.C. Keisling, E.C. Gordon, G.M. Palmer and A.D. Cox[1]

INTRODUCTION

Deep tillage with implements that have new designs continues to be of interest. This is especially true with the increasing weights of farm machinery and equipment that have sufficient weight to severely compact soil. Soil compaction can limit water infiltration, water storage and/or root penetration of the soil. Although many deep tillage experiments have been conducted in the past, they were conducted in late winter or early spring when soil was wet and gave no yield increases. Recent work suggested that with clays, fall tillage when the soil was dry would give yield responses to soybeans. Experiments were initiated to investigate the influence of the new equipment designs on deep fall tillage when the soil was dry.

The continued loss of soil organic matter also is contributing to compaction of soil. This compaction can be shallow and in the form of crusts that retard emergence and growth. An experiment was started in 1997 to assess the importance of these shallow crusts on end-of-the-season lint yield.

MATERIALS AND METHODS

Experiments were begun at the Northeast Research and Extension Center (NEREC), Keiser, Arkansas, on a Sharkey silty clay in 1993 and at Delta Branch, Clarkedale, Arkansas, on Dubbs-Dundee silt loam in 1996. Tillage experiments consisted of eight treatments arranged in a randomized complete block with eight replications at the two locations. The treatments were 1) check, 2) subsoil in fall with parabolic subsoiler in the seedling row, 3) subsoil in fall with parabolic subsoiler at a 45 degree angle to seedling row, 4) subsoil in spring with parabolic subsoiler in the seedling row, 5) subsoiling shallow in the fall with parabolic subsoiler in the seedling row, 6) para-till in fall with seedling row, 7) DMI winged tip straight shank run just beneath the plow pan in fall and 8) DMI winged tip straight shank run with tip 12 to 14 in. deep in fall.

Crusting experiments were begun in 1997 at Delta Branch on Dubbs-Dundee silt loam. The crusting duration was simulated by placing a 10-ft board over the seedling row at cracking and removing it at 2, 3, 5, 7 and 10 days later.

RESULTS AND DISCUSSION

Results from the deep tillage experiments are shown in Table 1. Note that at NEREC there is a year effect. The year effect was due primarily to treatments giving different yield responses from one year to the next. Other deep tillage treatments were somewhat intermediate between the check and the parabolic subsoiler in the fall. Of particular interest was the lack of response of the implements that did not disturb the soil surface significantly. Results from one year's data at Delta Branch indicate that different implements than those used at NEREC resulted in higher yields. This indicates that farmers may want to use different deep tillage implements on different soil types.

Shallow crusts that delayed plant emergence for more than two days reduced lint yields substantially (Fig. 1). Yield reductions of as much as 50% resulted from seedlings being trapped in a crust at the cracking stage for about four days. Seedings were observed to exhibit "big shank," broken hypocotyls and small cotylendary leaves.

Table 1. Lint yields at Northeast Research and Extension Center (NEREC), Keiser, Arkansas, and Delta Branch, Clarkedale, Arkansas.

Treatment	NEREC			Delta
Year	95	96	97	97
	------------------lb lint /acre-------------------			
1. Conventional	681a	555a	915a	830ab
2. Parabolic in fall	709a	589a	747a	836ab
3. Parabolic in fall 45	---	---	---	827ab
4. Parabolic in spring	733a	605a	848a	830ab
5. Parabolic shallow in fall	---	---	---	788b
6. Para-till in fall	700a	604a	816a	874a
7. DMI winged tip 12 to 14"	709a	555a	749a	871a
8. DMI winged tip just beneath plow pan in fall	---	---	---	809b

Fig. 1. Effect of length of time crust is in place from beginning cracking.

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NO-TILL PRODUCTION IN THE ARKANSAS SOYBEAN RESEARCH VERIFICATION PROGRAM

R.A. Klerk, J.D. Beaty, L.O. Ashlock, C.D. Brown and T.E. Windham[1]

INTRODUCTION

The Arkansas Soybean Research Verification Program (SRVP) was established 14 years ago to improve soybean production and profitability in Arkansas. In this program, the SRVP coordinator and county Extension agent prescribe Extension recommendations in a very timely manner, resulting in more profitable commercial soybean production. Essential to the program is participation from the individual soybean producer, cooperation from soybean researchers and Extension specialists and continued funding from the Arkansas Soybean Checkoff Program.

Research continues to indicate that no-till or reduced-tillage methods can produce yields comparable to those with conventional tillage and that certain inputs are often reduced (Mayhew et al., 1995). Therefore, 28 out of 102, or 27.5%, of the commercial soybean fields enrolled in the SRVP from 1993 to 1997 were planted no-till (Ashlock et al., 1993 through 1997). Twelve different soybean production systems are utilized in the SRVP. These include early-season, full-season, doublecrop (soybean following wheat) planting dates, with and without irrigation. These six systems are further divided into conventional and no-till practices. The early-season and doublecrop systems have the highest percentage of no-till entries. Agronomic and economic comparison of the doublecrop irrigated production system are presented since this system comprises the largest number of both no-till and conventional tillage fields (13 fields apiece) (Table 1).

MATERIALS AND METHODS

Twenty-six commercial soybean fields enrolled in SRVP were planted in a doublecrop irrigated production system between 1993 and 1997. Thirteen of these fields were planted no-till with the other thirteen planted using conventional tillage practices. The field size, planting date, row spacing, number of cultivations and yield are listed for these fields in Table 2.

Weed control was achieved with a variety of herbicides. Only one of the no-till planted fields received cultivation for weed control with eight of the conventional planted fields receiving at least one cultivation (Table 2).

Yields on the SRVP fields were calculated from weigh tickets and field size where possible. In some fields weigh wagons were used to determine yields. The yields reported are based on 13% moisture.

All operations and inputs into a field were compiled for economic evaluation. The budgets for each field were generated with the Mississippi State Budget Generator (MSBG) developed by Spurlock and Laughlin (1992). The MSBG is a computer-based budgeting program that estimates costs and returns for specified crop or livestock enterprises (Windham and Brown, 1998). The program contains data regarding the input quantities and prices as well as output levels and prices. Operating costs (seed, fertilizer, chemicals, fuel, labor and repairs) and ownership costs (depreciation, interest, taxes and insurance) were estimated for all SRVP fields on a per acre basis. Production costs for all the fields were recalculated using a constant set of equipment and input prices. This procedure eliminates many of the market influences that affect production costs but were unrelated to the production technology being evaluated.

RESULTS AND DISCUSSION

No-till represents another viable management tool for soybean producers in Arkansas to increase net returns from soybean. No-till practices have been used in a higher percentage of fields planted in the early-season or doublecrop production system. The average no-till doublecrop irrigated soybean yield during the period from 1993 to 1997 was 43.6 bu/acre. The conventionally tilled fields averaging 41.9 bu/acre (Table 2).

Comparisons between the no-till and conventionally tilled fields indicate that the no-till fields on average were smaller in size, 54 verses 65 acres, respectively, while the planting date for the no-till fields averaged four days earlier. The rows were also narrower in the no-till fields compared to the conventionally tilled fields, averaging 9.9 in. verses 23.5 in., respectively. The more narrow row spacing in the no-till fields undoubtedly was responsible for the fewer cultivations when compared to the conventionally tilled fields.

Table 3 indicates that the no-till SRVP fields had an average operating cost of $115.02/acre while the averaged operating costs for the conventionally tilled fields

[1]First and third authors are with Agron. Sec., Coop. Ext. Ser., Univ. of Ark., located at Little Rock, AR., second author is with Agron. Sec., Coop. Ext. Ser., Univ. of Ark., located at Monticello, AR., and other authors are with Agric. Econ. Sec., Coop. Ext. Ser., Univ. of Ark., located at Little Rock, AR.

were $124.42/acre. No-till fields reflected a higher operating cost in both seed and custom work, while conventionally tilled fields reflected higher operating costs for fertilizer, operating labor, irrigation labor and repair and maintenance (Table 4). Similar costs between the two methods were obtained with seed treatment, herbicide, diesel and interest. Herbicide costs were the highest operating cost for both systems.

Additionally, Table 3 depicts that ownership costs were similar with no-till fields having a $50.17/acre charge verses a $51.46/acre charge for conventionally tilled fields. The total costs (operating plus ownership) averaged $165.18/acre for the no-till fields and $175.88/acre for the conventional fields.

A ten-year average soybean price of $6.29/bu was used plus a 25% cropshare land rent for economic evaluation. Net returns for no-till were higher, with an average return of $40.61/acre while net returns for conventional till above total costs and land rent averaged $21.78/acre.

In addition, no-till offers many advantages to management in soybean production. These include planting earlier than would have been possible with tillage and the ability to save soil moisture at planting (especially beneficial in a doublecrop situation). This conservation of moisture will increase the chance of the crop obtaining a stand and even producing acceptable height prior to the first irrigation. A no-till cropping system also reduces soil loss from the field and protects the quality of area surface water.

CONCLUSIONS

The SRVP no-till fields were successful in lowering specified operating and ownership cost without losing yield potential. Operating and ownership costs were lower in no-till SRVP fields than in tilled fields. Yields of the no-till fields were slightly higher than those of the conventionally tilled fields. A quicker turn around in planting soybeans after wheat was achieved when planting no-till which can aid in establishing an adequate plant stand.

No-till also offers soybean producers an additional management tool. The use of no-till does allow quicker planting and better use of soil moisture when moisture is limited. Preservation of top soil and surface water are also gained from no-till soybean production.

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Table 1. Number of Soybean Research Verification Program fields under different production systems with no-till and conventional tillage practices. 1993-1997.

	Dryland		Irrigated	
	No-Till	Conventional	No-Till	Conventional
Early Season	3	1	1	0
Full Season	1	15	3	43
Double-crop	7	2	13	13

Table 2 is on the following page.

Table 3. Number of doublecrop irrigated Soybean Research Verification Program fields from 1993 to 1997 with average yield, operating cost, ownership, total cost, net return and net return with 25% land rent charge.

Item	No-Till	Conventionally Tilled
Number of Fields	13	13
Yield (bu/acre)	43.6	41.9
Operating Cost ($/acre)	$115.02	$124.42
Ownership Cost ($/acre)	$ 50.17	$ 51.46
Total Cost ($/acre)	$165.18	$175.88
Net Return ($/acre)	$109.21	$ 87.67
Net Return +25% Land Rent Charge ($/acre)	$ 40.61	$ 21.78

Table 4. Inputs of operating cost for doublecrop irrigated Soybean Research Verification Program fields from 1993-1997.

Item	No-Till	Conventionally Tilled
	--------------$/acre-------------	
Seed	$16.40	$14.48
Custom Work	$17.14	$13.72
Fertilizer	$ 8.69	$11.53
Seed Treatment	$ 1.33	$ 1.23
Herbicide	$34.21	$31.91
Operating Labor	$ 4.15	$ 7.33
Irrigation Labor	$ 4.24	$ 5.56
Diesel	$12.17	$13.33
Repair and Maintenance	$12.95	$16.27
Interest	$ 3.11	$ 3.58
Total	$114.39	$118.94

Table 2. County, field size, planting date, row spacing, number of cultivations and yields of SRVP fields in doublecrop irrigated production systems. 1993-1997.

No-Till County (Year)	Field Size	Plant Date	Row Space	Number of Cultiv.	Yield
	acre		in.		bu/acre
Jefferson (93)	90	6-21	19	1	39.5
Lonoke (93)	50	6-14	19	0	36.6
Prairie (93)	60	6-14	7.5	0	54.6
Jackson (94)	35	6-18	13	0	46.0
Jackson (95)	35	6-24	8	0	41.5
Lonoke (95)	40	6-12	7.5	0	49.1
Pulaski (95)	31	6-8	7	0	37.6
Lonoke (96)	50	6-17	7.5	0	42.0
Poinsett (96)	56	6-24	7.5	0	32.1
Pope (96)	37	6-15	7.5	0	54.0
Pulaski (96)	50	6-14	7.5	0	35.1
Craighead (97)	38	6-25	10	0	46.5
Lee (97)	125	6-23	7.5	0	52.8
Average	54	6-18	9.9	0.1	43.6

Conventional Tillage County (Year)	Field Size	Plant Date	Row Space	Number of Cultiv.	Yield
	acre		in.		bu/acre
Arkansas (93)	49	6-30	14	0	41.5
Lincoln (93)	30	6-22	15	2	23.3
Poinsett (93)	135	6-21	30	1	35.2
Randolph (93)	55	6-22	30	2	52.8
Arkansas (94)	53	6-17	30	3	39.3
Jefferson (94)	45	6-19	19	0	35.2
Lincoln (94)	30	6-27	30	1	36.7
Prairie (94)	109	6-25	30	2	52.4
Lincoln (95)	40	6-13	38	3	42.4
St. Francis (95)	130	6-19	7	0	45.8
Cross (96)	53	6-24	15	0	43.2
Independence (96)	34	6-18	15	0	51.6
Arkansas (97)	80	6-24	32	2	45.4
Average	65	6-22	23.5	1.2	41.0

INFLUENCE OF PLANTING DATE AND HARVEST DATE ON COVER CROP PERFORMANCE IN A CORN PRODUCTION SYSTEM

H.J. Mascagni, Jr. and D.R. Burns[1]

INTRODUCTION

Winter cover crops have become very popular, not only for erosion control, but also for soil nitrogen (N) contributed by leguminous covers. Research has indicated that cover crop growth should be terminated about three weeks prior to planting (Torrey, 1992), minimizing soil insect problems and also enhancing soil moisture status for the following crop. Additionally, winter cover crops may increase soil organic matter. This is very important for soils of northeastern Louisiana, particularly loessial soils of the Macon Ridge area and alluvial soils of the Mississippi River. Organic matter in these soils is extremely low due to intensive cropping over the years.

Optimal planting dates for corn in northern Louisiana range from mid-March to early April (Mascagni and Boquet, 1996). Thus, the ideal time for cover crop termination would be mid-February to mid-March. Biomass produced between planting and termination determines a cover crop's effectiveness. The more dry matter produced, the greater the benefits from soil erosion control, improved soil properties and N contribution from leguminous-type cover crops. The objective of this study was to determine the influence of cover crop planting date and termination date (harvest date) on dry weight for several winter cover crops that may be used in a corn production system.

MATERIALS AND METHODS

Field experiments were conducted in 1995/1996 and 1996/1997 on a Sharkey clay (very-fine, montmorillonitic, nonacid, thermic Vertic Haplaquepts) at the Northeast Research Station near St. Joseph, Louisiana, and on a Gigger silt loam (fine-silty, mixed, thermic Typic Fragiudalf) at the Macon Ridge Research Station at Winnsboro, Louisiana, to evaluate the influence of planting date and termination date (harvest date) on dry weight and N content of several winter cover crops that may be used in a corn production system. Cover crops evaluated were crimson clover ('Robin' and 'Dixie') (*Trifolium incarnatum* L.), berseem clover ('Bigbee') (*Trifolium alexandrinum* L.), Austrian winter pea (*Dolichos lignosus* L.), winter wheat ('Buckshot 2368') (*Triticum aestivum* L.) and native vegetation (only in 1997). Cover crop planting dates at St. Joseph were 18 October and 15 November in 1995 and 7 October, 4 November and 11 December in 1996. Planting dates at Winnsboro were 20 October and 15 November in 1995 and 3 0ctober, 1 November and 21 November in 1996.

Experimental design was a randomized complete block with four replications. Cover crop treatments were harvested 4 March and 1 April at both locations in 1996 and 18 March and 9 April at St. Joseph and 18 March and 10 April at Winnsboro in 1997. Total above-ground plant matter was collected from separate areas within each plot for each harvest date. Sampling area was 1 m^2 for each harvest date. Plant tissue was dried at 70 C, ground, and analyzed for total N. Analyses of variance of dry weight data were conducted using GLM procedures of SAS. The LSD ($P \leq 0.05$) was calculated for mean separation.

RESULTS AND DISCUSSION

St. Joseph

Each year, only the October planting date survived the winter with adequate stands on the Sharkey clay soil. In 1996, cover crop dry weight for the 4 March harvest date ranged from 537 lb/acre for Dixie crimson clover to 2497 lb/acre for Austrian winter peas (Table 1). Total N in harvested plant parts ranged from 15 lb N/acre for Dixie crimson clover to 118 lb N/acre for Austrian winter peas. Dry weight increased for each cover crop, except winter wheat, as planting date was delayed.

There were fewer differences for dry weight among cover crops in 1997. Dry weight ranged from 641 lb/acre for native vegetation to 2227 lb/acre for Austrian winter peas (Table 2). Dixie crimson clover, berseem clover, Austrian winter peas and winter wheat had similar dry weights. Dry weight at the 10 April harvest date increased for each cover crop, except Austrian winter peas.

Winnsboro

In 1996, only the 20 October planting date survived the winter with an adequate stand. Dry weight for the 4 March harvest date ranged from 854 lb/acre for berseem clover to 1818 lb/acre for Austrian winter peas (Table 3). Total N in harvested plant parts ranged from 30 lb N/acre for winter wheat to 67 lb N/acre for Austrian winter pea. Dry weight at the second harvest date increased for each cover crop, except for winter wheat.

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The 3 October and 1 November planting dates in 1997 had adequate stands; however, the 21 November planting date did not survive the winter in 1997. Highest cover crop dry weight occurred at the 3 October planting date (Table 4). Both crimson clovers, Austrian winter peas and winter wheat had similar dry weights for each planting date. Each crimson clover doubled in dry weight as harvest date was delayed, probably accounting for the significant cover crop x harvest date interaction.

SUMMARY

In summary, cover crops should be planted in north Louisiana no later than October, particularly on the poorly drained clay soils, for maximum biomass production. On the clay soil at St. Joseph, Austrian winter peas had the most consistent performance for biomass production. Crimson clover, Austrian winter peas and winter wheat had the highest dry weight on the loessial silt loam of the Macon Ridge. Austrian winter peas had the highest N content of the four legume cover crops evaluated. Total N in harvested plant parts indicates that Austrain winter peas > crimson clover > berseem clover > wheat in providing N for subsequent crops.

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Table 1. Influence of two harvest dates on dry weight, nitrogen (N) content and N in harvested plant parts of five cover crops (planted 18 October 1995) on Sharkey clay at St. Joseph, Louisiana in 1996.

	March 4			April 1		
Cover Crop	Dry wt.	N	N content	Dry wt.	N	N content
	lb/acre	%	lb N/acre	lb/acre	%	lb N/acre
Crimson Clover (‘Robin’)	544	3.43	18.8	2331	2.19	50.0
Crimson Clover (‘Dixie’)	537	2.49	14.7	1771	2.52	47.3
Berseem Clover	806	4.17	33.6	2181	3.20	69.5
Austrian Winter Peas	2497	4.68	117.9	3300	2.79	89.4
Wheat	1305	1.78	23.2	1232	1.34	16.4
LSD (0.05)	229	0.74	21.4	1108	0.69	25.7

Table 2. Influence of two harvest dates on dry weight of six cover crops (planted 7 October 1996) on Sharkey clay at St. Joseph, Louisiana in 1997.

Cover Crop	March 18	April 10
	---dry weight, lb/acre---	
Crimson Clover (‘Robin’)	1434	4393
Crimson Clover (‘Dixie’)	1850	3901
Berseem Clover	2226	4140
Austrian Winter Peas	2227	2202
Wheat	2004	2509
Native Vegetation	641	1534
LSD (0.05)	521	1106

Table 3. Influence of two harvest dates on dry weight, nitrogen (N) concentration, and N in harvested plant parts of five cover crops (planted 20 October 1995) on Gigger silt loam at Winnsboro, Louisiana, in 1996.

	4 March			1 April		
Cover Crop	Dry wt.	N	N content	Dry wt.	N	N content
	lb/acre	%	lb N/acre	lb/acre	%	lb N/acre
Crimson Clover (‘Robin’)	1596	3.71	59.0	2199	3.50	77.5
Crimson Clover (‘Dixie’)	1489	3.44	51.2	2619	3.67	95.7
Berseem Clover	854	2.98	25.7	1284	3.32	42.2
Austrian Winter Peas	1816	3.75	66.8	2444	3.59	87.7
Wheat	1382	2.19	30.2	1215	2.29	26.9
LSD (0.05)	307	0.68	10.2	562	0.79	18.7

Table 4. Influence of two planting dates and harvest dates on dry weight of six cover crops (planted 1996) on Gigger silt loam at Winnsboro, Louisiana, in 1997.

	Harvest Date		
Cover Crop	18 March	10 April	Average
	----------dry weight, lb/acre----------		
Planting Date - October 3			
Crimson Clover ('Robin')	3004	6608	4806
Crimson Clover ('Dixie')	2819	7885	5352
Berseem Clover	1640	3071	2356
Austrian Winter Peas	2771	4382	3577
Wheat	2841	3585	3213
Native Vegetation	734	961	848
Average	2302	4415	3359
Planting Date - November 1			
Crimson Clover ('Robin')	1861	6474	4168
Crimson Clover ('Dixie')	2118	3605	2862
Berseem Clover	861	3231	2046
Austrian Winter Peas	1818	3439	2629
Wheat	1914	2155	2035
Native Vegetation	296	1489	893
Average	1478	3399	2439
Planting Date - Average			
Crimson Clover ('Robin')	2433	6541	4487
Crimson Clover ('Dixie')	2469	5745	4107
Berseem Clover	1251	3151	2201
Austrian Winter Peas	2295	3911	3103
Wheat	2378	2870	2624
Native Vegetation	515	1225	870
LSD (0.05):			
Planting Date (PD)	492		
Cover Crop (CC)	852		
Harvest Date (HD)	492		
CC X HD	1206		

PREPLANT HERBICIDES FOR WEED CONTROL IN CONSERVATION-TILLAGE COTTON (*GOSSYPIUM HIRSUTUM* L.)

Marilyn R. McClelland, M. Cade Smith and Preston C. Carter[1]

INTRODUCTION

Conservation-tillage cotton production is becoming more common in Arkansas and throughout the Cotton Belt because of increased production efficiency and for soil conservation under federal compliance guidelines. The term "conservation tillage" encompasses several practices of reduced tillage, including stale seedbed, minimum or reduced tillage, ridge tillage, strip tillage, mulch tillage and no-till. Several of these terms are briefly described as methods of residue management in a review article by Locke and Bryson (1997). In most of these systems, however, no tillage is performed for several weeks or months before planting (Locke and Bryson, 1997; Hydrick and Shaw, 1995; Webster and Shaw, 1997). Weed control at planting, therefore, is a major concern (McWhorter and Jordan, 1985; Worsham and Lewis, 1985). Cotton is a poor competitor early in the season, and it is important that vegetation be controlled during the seedling stage of growth.

Postemergence herbicides, such as Roundup, that can be used over-the-top of transgenic cotton cultivars and control a wide spectrum of winter and early-spring annual weeds are becoming an option for producers who choose to use this emerging technology. However, heavy infestations of green vegetation can interfere with planting, in which case it is advisable to achieve weed-free conditions prior to cotton emergence to successfully produce a conservation-tillage cotton crop.

The burndown herbicides Gramoxone Extra and Roundup are currently the foundation of most burndown programs in conservation-tillage cotton. However, these herbicides often do not control all emerged weeds, and neither Roundup nor Gramoxone Extra provides residual weed control to suppress new weed emergence (Baughman et al., 1995; Frans et al., 1994; Guy, 1995a; Reynolds et al., 1994).

Some winter weeds, such as horseweed [*Conyza canadensis* (L.) Cronq.], Pennsylvania smartweed (*Polygonum pensylvanicum* L.), cutleaf eveningprimrose and Italian ryegrass (*Lolium multiflorum* Lam.), may persist into the cotton growing season and are difficult to control with a single, burndown herbicide (Fairbanks et al., 1995; Guy, 1995a; Guy and Ashcraft, 1995). Roundup has been good for controlling small horseweed, but control of cutleaf eveningprimrose has been erratic (Guy and Ashcraft, 1995). Tank-mixing a residual herbicide with Roundup or Gramoxone Extra can increase control of many weeds over control with either of the herbicides alone (Baughman et al., 1995; Frans et al., 1994), although antagonism of these mixtures on some weeds has been reported (Hydrick and Shaw, 1995; Webster and Shaw, 1997). Residual herbicides can also extend control into the early season. If weeds are not controlled prior to or soon after cotton emergence, they have the potential to interfere with crop production and decrease cotton yields. The objective of these experiments was to evaluate several herbicide combinations for preplant weed control in reduced-tillage cotton.

MATERIALS AND METHODS

Field experiments were conducted in 1994 through 1996 at the Cotton Branch Experiment Station, Marianna, Arkansas, on a Calloway silt loam to evaluate activity of burndown herbicides on natural winter weed infestations. Plot areas were fallow the year prior to establishment of each experiment and were not disturbed by tillage before spraying preplant treatments. Plot size was 6 by 25 ft, and each treatment was replicated four times.

Herbicides were applied 18 March 1994, 21 March 1995 and 17 March 1996, with a backpack sprayer in 20 gal/acre at 20 to 40 psi. All herbicide rates are expressed as lb of active ingredient per acre (lb ai/acre). Non-ionic surfactant (Induce) at 0.5% by volume was added to each treatment.

Average weed sizes and densities of prevalent weeds at the time of planting are presented in Table 1. Because of the different growth habits of winter weeds, size information is very general. Weeds were rated visually by species for percent control (0 = no control and 100 = death or absence of plants) compared to an untreated check plot. A rating of "total burndown," which was percentage control of total vegetation in the plots, was also evaluated. Miscellaneous species, including pineappleweed, shepherds–purse, sibara, white clover, wild garlic, henbit, annual bluegrass, horseweed, common chickweed, mouseear chickweed, paleseed plantain and various grass (*Graminaea*) species, present at low infestations or controlled with all treatments or rated individually only one year, are reported as part of the total burndown. At 6 weeks after treatment

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(WAT), summer annual weeds such as morningglory, pigweed and goosegrass were emerging, but little biomass had accumulated. Gramoxone Extra was applied at cotton planting to control emerging weeds, so these species were rated only as part of the total burndown rating. Plots were rated 2 and 4 WAT in 1994 and 2, 4 and 6 WAT in 1995 and 1996. Because the 2 WAT rating of cutleaf eveningprimrose is representative of total control at that time, only 4 and 6 WAT ratings are presented for total control.

Four rows of cotton 'DPL 51' were planted across all plots 20 May 1994, 17 May 1995 and 9 May 1996 to evaluate cotton tolerance to the preplant burndown herbicide treatments. Gramoxone Extra was applied over the entire area at planting to control emerged summer annual weeds and vegetation not controlled by the burndown treatments. Cotton was rated visually for percent injury approximately three weeks after planting. Data were analyzed by analysis of variance, and means were separated by protected LSD at the 0.05 level of significance.

RESULTS AND DISCUSSION

Because cutleaf eveningprimrose was the predominant species each year, discussion will center around its control and total burndown. Tank mixtures containing Roundup and Gramoxone Extra generally controlled winter weed species such as chickweed species, shepherdspurse, henbit and annual bluegrass (data not shown). Control of these species was usually less with Roundup or Gramoxone Extra alone than with a tank mixture containing a residual herbicide.

Cutleaf Eveningprimrose Control

A heavy, uniform population of cutleaf eveningprimrose was present at Marianna all years (Table 1). Activity of Gramoxone Extra on cutleaf eveningprimrose was faster than activity of Roundup (Table 2). At the 2 WAT rating, control with Roundup was 10% to 38% compared with 61% to 100% control with Gramoxone Extra. However, control with Roundup had increased by 4 WAT.

In 1994 at 4 WAT, all tank mixtures with Roundup controlled primrose better than Roundup alone. Of the Gramoxone Extra mixtures, those that equalled control of Roundup mixtures were Staple, Bladex, Karmex, Caparol and Lorox. These Gramoxone Extra treatments also gave fair to good primrose control (75 to 88%) at 4 WAT in 1995. By 6 WAT in 1995, treatments that controlled primrose better than Roundup alone (75%) were Banvel, 2,4-D, Staple, Karmex plus Roundup, 2,4-D plus Gramoxone Extra and the three-way mixtures (2,4-D plus Gramoxone Extra plus Bladex, Karmex or Caparol). The large decrease in cutleaf eveningprimrose control at 6 WAT with Gramoxone Extra alone and in some mixtures was the result of regrowth from plants that were not completely controlled with this contact herbicide. Activity of Roundup was much slower than that of Gramoxone Extra, but because Roundup is readily translocated, regrowth was less.

In 1996, primrose control tended to be better with Gramoxone Extra than with Roundup treatments (Table 2). The only tank-mix herbicides that added to Roundup activity by 4 WAT in 1996 were Bladex, Karmex and Goal. By 6 WAT, control with Goal had declined dramatically, but control with 2,4-D and Caparol had increased to 85 and 73%, respectively. Although antagonism has been reported for several herbicides in tank mixture with Roundup (Webster and Shaw, 1997), that is probably not the explanation for low control in 1996 since control with Roundup alone was extremely low. Climatological conditions, including frost after treatment in 1996, probably resulted in activity differences among years.

Roundup or Gramoxone Extra plus 2,4-D gave at least 85% control of cutleaf eveningprimrose at 6 WAT (2,4-D was not mixed with Gramoxone Extra in 1994). Activity of 2,4-D plus Roundup appeared to be slower in 1996 than in 1994 and 1995. Control of primrose with 2,4-D plus Gramoxone Extra was not significantly enhanced by the addition of Bladex, Karmex or Caparol, although there was a numerical trend for higher control with the three-way mixture in 1996. Guy (1995b) also reported that 2,4-D, either alone or mixed with Roundup, controlled cutleaf eveningprimrose. There is, however, a question of safety to the cotton crop with 2,4-D. 2,4-D can injure cotton significantly if applied 2 weeks or less before cotton planting, but cotton was tolerant to applications made 4 weeks or more before planting (Guy 1995b).

Fairbanks et al. (1995) reported that 0.012 or 0.024 lb/acre of the package mixture of Harmony Extra with Gramoxone Extra increased control of cutleaf eveningprimrose over that of Gramoxone Extra alone, but control with Roundup was not enhanced. In our study, however, control with Gramoxone Extra was not enhanced by the addition of Harmony Extra except for a slight increase in control at 4 WAT in 1996 (Table 2). Control from Roundup, however, was increased from 78% when applied alone to 99% with the addition of Harmony Extra in 1994 and from 25 to 60% in 1996. In 1995, the addition of Harmony Extra did not significantly increase primrose control over that with Roundup alone.

Goal, Reflex, Cobra and Blazer (diphenylether herbicides) increased Roundup control of cutleaf eveningprimrose to at least 95% in 1994 and 82% in 1995 at 4 WAT (Table 2). In 1995, however, primrose control with the Roundup plus diphenylether treatments was generally poor by 6 WAT. In general, these herbicides did not increase control with Gramoxone Extra.

Total Burndown

As with cutleaf eveningprimrose control, total burndown ratings were generally better with Gramoxone Extra than with Roundup at 2 WAT (data not shown), primarily because of rapid activity of Gramoxone Extra. In 1994, tank-mix herbicides that enhanced total control over that with Roundup alone were Banvel, Harmony Extra, Bladex, Karmex, Caparol, Reflex, Cobra and Blazer. Total control with Roundup mixtures tended to be lower than control of cutleaf eveningprimrose, perhaps because wild garlic control with most Roundup treatments was low at 4 WAT (10 to 65%). Total control with Gramoxone Extra treatments in 1994 ranged from 61 to 89%. Gramoxone Extra plus Bladex gave higher control (89%) than Gramoxone Extra plus Karmex, Caparol and the diphenylethers.

Although total control with Roundup was enhanced slightly by diphenylether herbicides in 1994, there was no enhancement in 1995. Gramoxone Extra activity was not increased with addition of those herbicides either year. However, other studies have shown improved control of some species with the addition of Goal to Roundup or Gramoxone Extra (Baughman et al., 1995; McClelland et al., 1995). In 1995, herbicides that added to Roundup control at 4 WAT were 2,4-D, Karmex and Cobra. Gramoxone Extra mixtures that performed well in 1995 were Gramoxone Extra with Banvel, 2,4-D, Bladex, Karmex and Caparol. Horseweed was present in the 1995 experiment. Although most Roundup mixtures controlled horseweed, only Bladex and Banvel aided in horseweed control with Gramoxone Extra (data not shown). Gramoxone Extra plus Bladex, however, does not always control horseweed, and Roundup is a better burndown choice than Gramoxone Extra for horseweed (Guy, 1995b). Horseweed was not present in 1994 or 1996.

Gramoxone Extra mixtures generally gave better total weed control than Roundup mixtures in 1996. The presence of wild garlic, which was controlled better with Gramoxone Extra than with Roundup mixtures (data not shown), probably influenced total control, as did the poorer control of cutleaf eveningprimrose with Roundup that year.

Herbicides that gave greater than 70% total control for 4 to 6 WAT in all three years of experiments were Bladex and Karmex plus either Roundup or Gramoxone Extra (Table 2). Other treatments that controlled most weeds consistently included 2,4-D plus Roundup, Harmony Extra plus Roundup, Caparol plus Gramoxone Extra and Banvel plus Gramoxone Extra or Roundup.

Total burndown control was greater than 90% with the three-way mixtures of 2,4-D plus Gramoxone Extra plus Bladex, Karmex or Caparol (Table 2). Total burndown control was at least 91% at 6 WAT with the three-way mixtures compared to 70 to 80% with 2,4-D plus Gramoxone Extra. Increased total control with the three-way mixtures is probably due to control by the residual herbicides of summer annuals, especially grass species, that were emerging by 6 WAT. However, Gramoxone Extra was always applied at cotton planting because all plots had at least a few emerging weeds.

Cotton Tolerance

Cotton was not significantly injured by any of the burndown treatments at the 5% level of significance (data not shown). Injury was generally higher in 1996 (4 to 30%) than in 1994 and 1995 (0 to 5%), probably because of difficulty planting into a rougher seedbed in 1996. Guy (1995a) reported cotton injury only from 2,4-D, Banvel and Harmony Extra if application was made within two weeks of planting. The residual herbicides such as Bladex, Karmex, Lorox and Caparol could be used safely even when applied within one week of planting. Generally, herbicides can be used safely if applied at least four weeks before planting and if rainfall occurred after application, but before planting (Guy, 1995a).

In summary, there were a number of options for preplant weed control in no-till cotton. Bladex and Karmex with Gramoxone Extra or Roundup gave the most consistent control for all three years of experiments. Banvel, 2,4-D, Harmony Extra, Staple and Caparol were also generally good tank-mix partners with Gramoxone Extra and Roundup for control of winter weeds, including cutleaf eveningprimrose. Three-way mixtures of Gramoxone Extra plus 2,4-D plus Bladex, Karmex or Caparol gave excellent broad-spectrum control. Even with a residual herbicide, all plots were sprayed with Gramoxone Extra at planting to control regrowth of winter weeds and emerging weeds that would otherwise interfere with emerging cotton.

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Table 1. Size and density of prevalent weeds in March at Marianna, Arkansas.

	Year					
	1994		1995		1996	
Weed species	Size	Density	Size	Density	Size	Density
	cm	no/m^2	cm	no/m^2	cm	no/m^2
Cutleaf eveningprimrose	15	10-22	10	24	20	8
Henbit	10	<10	15	16	15	50
Mouseear chickweed	5	<10	4	12	3	20
Annual bluegrass	7	15	4	48	3	70
Common chickweed	--	--	4	24	4	60

Table 2. Burndown control of weeds with herbicide mixtures at Marianna, Arkansas, 1994-1996[1].

		Cutleaf eveningprimrose								Total burndown[2]				
		1994		1995			1996			1994	1995		1996	
Herbicide	Rate	2 WAT[3]	4 WAT	2 WAT	4 WAT	6 WAT	2 WAT	4 WAT	6 WAT	2 WAT	4 WAT	6 WAT	4 WAT	6 WAT
	lb ai/acre	%												
G = tank mixed with Roundup, 0.75 lb ai/a + Induce, 0.5%:														
Roundup alone	0.75	38	78	10	72	75	29	54	25	65	86	79	63	58
Banvel + G	0.25	79	97	23	78	99	--	--	--	82	83	81	--	--
2,4-D amine + G	0.5	65	100	45	90	96	28	48	85	66	94	88	53	54
Harmony Extra + G	0.016	65	99	16	76	82	31	51	60	86	83	84	60	80
Staple + G	0.062	62	96	28	81	91	--	--	--	80	88	81	--	--
Bladex + G	1.0	84	100	36	80	75	43	78	81	90	86	81	82	87
Karmex + G	1.0	98	100	42	92	88	30	79	95	84	94	92	78	79
Caparol + G	1.0	92	99	48	81	76	21	45	73	84	87	79	49	53
Lorox + G	1.0	100	100	50	83	80	--	--	--	80	89	85	--	--
Goal + G	0.25	74	98	48	82	67	66	79	38	74	88	71	82	64
Reflex + G	0.25	95	99	55	84	69	--	--	--	86	88	72	--	--
Cobra + G	0.10	92	100	59	86	72	--	--	--	84	93	76	--	--
Blazer + G	0.25	92	95	48	84	64	--	--	--	86	88	70	--	--
P = tank mixed with Gramoxone Extra, 0.63 lb ai/a + Induce, 0.5%:														
Gramoxone Extra alone	0.63	100	69	61	61	45	86	60	49	74	71	46	71	60
Banvel + P	0.25	--[4]	--	79	89	78	88	79	79	--	93	82	89	86
2,4-D amine + P	0.5	--	--	85	99	99	87	86	88	--	95	80	82	70
Harmony Extra + P	0.016	89	79	64	65	40	89	76	52	80	74	45	82	81
Staple + P	0.062	89	95	70	80	68	--	--	--	82	86	62	--	--
Bladex + P	1.0	91	98	76	85	75	90	91	88	89	90	81	95	92
Karmex + P	1.0	96	88	66	84	74	92	89	92	71	89	81	91	85
Caparol + P	1.0	100	100	80	88	77	85	90	94	69	94	80	91	86
P = tank mixed with Gramoxone Extra, 0.63 lb ai/a + Induce, 0.5%:														
Lorox + P	1.0	98	96	62	75	54	--	--	--	78	81	61	--	--
Goal + P	0.25	65	46	65	62	39	94	76	68	62	72	44	86	74
Reflex + P	0.25	71	55	59	65	42	--	--	--	61	72	50	--	--
Cobra + P	0.10	75	36	79	71	45	--	--	--	64	78	49	--	--
Blazer + P	0.25	77	75	72	66	44	--	--	--	63	74	74	--	--
2,4-D +	0.5													
Bladex + P	1.0	--	--	93	100	100	95	99	100	--	100	96	97	100
2,4-D +	0.5													
Karmex + P	1.0	--	--	92	99	99	93	99	99	--	99	97	93	91
2,4-D +	0.5													
Caparol + P	1.0	--	--	99	100	100	94	98	98	--	100	93	93	92
LSD (0.05)		14	16	10	8	8	16	13	18	15	6	9	10	12

[1]Treatments were applied 18 March 1994; 21 March 1995; and 17 March 1996.

[2]Species in 1994 were cutleaf eveningprimrose, henbit, white clover, pineappleweed, shepherdspurse, and paleseed plantain; species in 1995 were cutleaf eveningprimrose, annual bluegrass, mouseear and common chickweed, horseweed, and henbit; species in 1996 were cutleaf eveningprimrose, shepherdspurse, henbit, mouseear and common chickweed, wild garlic, and pineappleweed.

[3]WAT: weeks after treatment.

[4]Dash '--' in means columns indicates the treatment was not applied or data were not available in that year.

IDENTIFICATION OF CRITICAL SOURCE AREAS FOR CONTROL OF SEDIMENT AND PHOSPHORUS TRANSPORT WITHIN A LARGE WATERSHED

J.M. McKimmey and H.D. Scott[1]

ABSTRACT

Agricultural practices such as animal waste applied to pastures have been implicated as a major non-point source of phosphorus. This study used the Universal Soil Loss Equation (USLE) and the Phosphorus Index (PI) in a geographical information system to 1) estimate potential sediment and phosphorus (P) source areas in the War Eagle Watershed in northwestern Arkansas and 2) determine the land cover and management parameters most influential in estimation of offsite transport of P. The USLE estimated that 2.2% of the watershed had potential erosion rates greater than 34 Mg/ha. The PI model estimated that 2.1% of the watershed was very highly vulnerable at the highest P fertilizer application rate. In all simulations, erosion from areas of poor ground cover and all fertilizer application rates were the most influential variables in identifying vulnerable areas. These variables can be modified by best management practices to reduce erosion and P transport.

INTRODUCTION

In many regions of the U.S., crop production is the dominant land use. Reports have cited agriculture as the largest contributor of non-point source pollution in the United States (Moreau, 1994). However, agricultural areas can also encompass other forms of land use and land cover such as roads, stream banks and septic filter fields. The impact of these and other non-agricultural uses within agricultural classifications are often associated with the effects of agricultural production.

In northwestern Arkansas, the public perception is that the quality of ground and surface waters has deteriorated over the past 30 years. During this time the population of the area has more than doubled, and industry has diversified from mostly small farms to a mixture of light industry, processing plants and poultry and swine operations. With these changes in demography, potential problems associated with water quality have also increased. Animal wastes, primarily poultry litter, are commonly broadcast to area pastures as an inexpensive organic fertilizer, thereby causing concern for the degradation of surface water quality from subsequent runoff of nutrients. Current public concerns are focused on maintenance and improvement of surface water quality by reducing nutrient loading, fecal coliform counts and other pollutants. There is a need to examine the impact of animal waste disposal on PO_4-P concentrations in streams and lakes and to identify areas that are vulnerable to sediment and nutrient transport.

The objectives of this study were to 1) identify critical source areas for sediment and phosphorus transport in a large watershed by using two models and 2) demonstrate the effectiveness of geographical information systems (GIS) in estimation and evaluation of potential erosion and P transport source locations within a large watershed.

The two models designed to accomplish these tasks on a field basis were the Universal Soil Loss Equation (USLE) and the Phosphorus Index Model (PI). The USLE was developed for use by the National Resources Conservation Service (NRCS) and other governmental agencies to predict annual sediment yield from rill/inter-rill erosion. The governing equation is given as

$$A = R * K * L * S * C * P \qquad [1]$$

where A is the soil loss (kg/ha/year), R is the rainfall index, K is the soil erodibility factor, LS is the slope and slope length factor, C is the cropping factor, and P is the conservation factor (Wischmeier and Smith, 1978).

The PI model was developed for the NRCS as a field assessment tool to estimate the vulnerability of a site to phosphorus (P) transport via surface runoff (Lemunyon and Gilbert, 1994). This model was designed to account for P transport in both sediment and dissolved forms of P and is expressed as

$$PI = \Sigma\, k_i\, W_i \qquad [2]$$

where K_i is the site characteristic factors *i* associated with P transport and W_i is the weight associated with factor *i*. Factors important in the PI model included 1) SE, a classified version of soil erosion that originates from the USLE, 2) SR, the surface runoff class derived from soil permeability and slope, 3) STP, the soil test P, 4) IPR, the inorganic P_2O_5 application rate, 5) IPM, the inorganic P_2O_5 application method, 6) OPR, the organic P_2O_5 application rate and 7) OPM, the organic P_2O_5 application method. The W_i is the weight reflecting each factor's influence on P transport vulnerability (Table 1). Factors SE, SR, STP, IPR, IPM, OPR and OPM are site characteristics that influence P transport and are assigned a phosphorus loss

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rating value (PLR) according to a site's condition in the field. Each PLR is multiplied by the associated weight, and the products are summed over all site characteristics, yielding a PI. Indices are classified according to qualitative descriptions of P vulnerability to transport. The four descriptions are low, medium, high and very high and correspond to PI indices of < 8, 8 to 14, 15 to 32 and > 32, respectively (Table 1).

Both models were intended to be used with data collected in the field. From these models, best management practices can be recommended for a particular field. Neither of these models, however, attempts to quantify transport processes, nor do they suggest movement from a site. Rather, they report a relative potential for movement.

The fact that both the USLE and the PI are field-based models suggests that assessment of sediment and P transport potential using these models on a watershed basis is inappropriate. However, the use of raster-based GIS allows such a task to be achieved by applying a grid over a study area where actual ground area, as represented by each cell (pixel), is determined by the user. Simple mathematical operations such as the USLE and the PI are executed by inputting different data themes (attributes) as equation parameters. Calculations and equation results are made on a pixel-by-pixel basis until all of the pixels in the grid have been examined and combined to produce a composite map of the study area. Thus, model calculations are possible on a watershed basis using a raster-based GIS because model calculations are performed on each individual pixel. Although the pixel can be set to any size, pixel size (resolution) is a function of several factors. One of these factors is the scale of the original data used to compile the database. If the source data scale is large enough, i.e., a large map of a small area, it is possible to have a resolution equal to or often smaller than the actual fields within a study area.

METHODS

Study Location and Characteristics

The War Eagle Watershed (WEW) is the largest subbasin in the Beaver Lake Watershed in northwestern Arkansas and consists of about 86,440 ha in Madison and Carroll Counties (Fig. 1). The War Eagle Watershed is located between two physiographic regions, the Boston Mountains and the Springfield Plateau, which are separated by the Boston Mountain Escarpment. Predominant agricultural practices in the watershed are poultry and cattle production, often run in conjunction on the same farm. Poultry litter is applied to area pastures as a fertilizer at varying application rates ranging between 734 and 1,468 kg/ha/year, with application frequencies between one and two times per year.

This study included the application of the USLE and the PI models using GIS techniques and primary attributes in a digital spatial database. The WEW database was developed from various source materials and methods detailed by McKimmey (1994). Sources used to compile the spatial database included NRCS Order II soil surveys, Digital Elevation Models (DEM) generated by the U.S. Geological Survey and land use/land cover (LULC) generated by the Tennessee Valley Authority from black and white as well as color infrared aerial photography. All source data were generated at a scale of 1:24,000. Raster data generated from these sources were created with a 30-m resolution. The GIS software used in the study was Geographic Resource Analysis Support System (GRASS) (CERL, 1992).

Elevations for the WEW range from 341 to 763 m above sea level. Topography is mostly steep hill slopes with narrow valleys and ridges. A majority of these slopes range from 3 to 12 degrees. Geology and soils of the WEW reflect the physiographic regions with a greater proportion of sandstone, shale bedrock and clayey soils found in the Boston Mountains. This region also had the highest proportion of slow to moderately permeable soils. Dominant soil taxonomic units are the Nella-Steprock-Mountainburg complex and the Enders-Leesburg complex. Dominant soils in the Springfield Plateau are Nixa, Clarksville and Noark series. Nearly 57% of the watershed is in forest with pastures composing slightly over 38% and scrub brush and rangeland nearly 2%. The spatial distribution of urban areas in the WEW was insignificant.

Model Implementations

Most parameters of the USLE were simple classifications of primary attributes (McKimmey 1994). Briefly, the rainfall index was 616 Mg/ha/year and was obtained from an isoerodent map (Wischmeier and Smith, 1978). Soil erodibility was created by classifying soil mapping units to K factor values based upon county soil survey data (USDA-SCS, 1984; USDA-SCS, 1986). Cover factors were produced by classifying LULC according to the USLE publication guidelines (USDA-SCS, 1983). Cover factors of each LULC category were chosen based upon general characteristics observed within the watershed. Infrared aerial photography was used to determine vigor of vegetative growth for each pasture in the watershed. From these data unique C factors were assigned to each pasture category. Prevention factors were not used in this study due to the minimal coverage of row crops in the watershed.

The LS parameter in equation [1] is defined as the ratio of the estimated soil loss for a particular slope and slope length to the soil loss from a standard slope of 9% and a length of 22.1 m. Slope length is the distance from where runoff begins to where deposition begins at a decrease in slope or where runoff enters a well-defined channel (Wischmeier and Smith, 1978). We found that it was easier to use the original equation given as

$$LS = \left(\frac{\lambda}{22.1}\right)^m * (19.94 + \sin^2\theta + 1.39 \sin\theta + 0.02) \quad [3]$$

where LS is slope and slope length factor, λ is a slope length map, *m* is a slope correction coefficient map, and T is a slope map in degrees from horizontal. Slope maps were calculated from the DEMs within GRASS. Variable *m* was constructed by classifying a percent slope map according to criteria given by Wischmeier and Smith (1978). A map representing λ was generated on a cell basis by evaluating all eight surrounding cells for changes in slope, slope aspect, elevation and blocking factors such as roads and streams (McKimmey, 1994). Values on the final λ map represented a cell's position in a slope. The final LS factor map was generated by inserting values from maps λ, *m* and T into equation [3] for each cell in the watershed.

These procedures created raster maps for factors K, LS and C for the whole watershed. Annual soil loss was determined by multiplying the single value for R and all three maps together for each 30-m cell in the watershed.

The parameters for the PI model were obtained from maps and experimental data. Soil erosion (SE) was a classification of the USLE map based upon the P loss rating (PLR) in Table 1. Surface runoff class (SR) was a combination of the slope and soil permeability. Areas with slight slopes and rapid soil permeability were classed as having negligible influence on P transport, and steep slopes and low soil permeability were most influential in P transport. This map was created by combining a soil permeability map, classified from the soil mapping unit map, with the percent slope map according to the previous logic. Soil test P (STP) data were derived from field data collected by county extension and NRCS offices. Since exact locations of the soil samplings were not available, median STP values were taken as representative of the soil mapping unit from which they were taken. These STP values were classified into PLR values of low, medium, high or excessive (Table 1). The STP map was created by classifying soil maps according to these PLR values. Areal distribution of each parameter is given in Table 2.

The PI model was run within GRASS using the compiled spatial database. The PI model calculations were restricted to pastures, scrub brush and poultry operations, which are potential locations that could receive poultry litter. The PI model was initially calculated to evaluate the current status of areas vulnerable to P transport without the addition of any fertilizer or poultry litter. Next, the PI model was run to simulate the effects of the addition of two types of P_2O_5 fertilizer applied at four rates of application. All simulated P_2O_5 fertilizer applications, applied broadcast more than three months before the growing season, corresponded to a PLR of 8.0 in the very high category (Table 1). For simulations of the addition of inorganic P_2O_5 fertilizer (IPR), the PLR was set to 1 (low), 2 (medium), 4 (high) or 8 (very high). Table 1 shows the corresponding inorganic P_2O_5 fertilizer application rates. Values of OPR and OPM in equation [3] were set to zero. For simulations of the addition of organic P_2O_5 (OPR), PLR were the same as the inorganic form, but applications rates were based on rates of poultry litter having an average of 20.2 kg/Mg P_2O_5. In these simulations OPR was set at either 1.0 (1.12 Mg/ha of poultry litter), 2 (2.24 Mg/ha), 4 (4.5 Mg/ha) or 8 (9.0 Mg/ha), and values of IPR and IPM in equation [3] were set to zero. Therefore, organic P_2O_5 sources were considered to contribute more to P transport vulnerability than inorganic sources, as reflected by the differences between IPR and OPR site characteristic weights and category ranges allocated to fertilizer application rates for the P loss ratings (Table 1).

RESULTS AND DISCUSSION

Erosion in the Watershed

Estimated annual total rill/inter-rill erosion for the WEW was 430,558 Mg/year, which equates to an average of 4.98 Mg/ha/year (Fig. 1; Table 3). This estimated potential erosion does not include soil loss from paved or unpaved roads and ditch banks. Nearly 58% of the watershed had estimated erosion rates of less than 2.3 Mg/ha/year, and over 85% of the watershed had estimated erosion rates less than 4.5 Mg/ha/year. These results indicate that there is not a severe erosion problem within the WEW watershed as a whole. However, 2.2% of the watershed had severe annual erosion rates greater than 33.6 Mg/ha/year.

Distributions of the input parameters across erosion classes were investigated to determine the most influential parameters for both low and high erosion classes. For each class of attributes, the distribution was divided by the total distribution for the WEW. The bold values in Table 4 indicate percent coverages that were more than 1.5 times the total WEW coverage. These values were considered to be more influential in erosion despite the fact that they may not have had the largest distribution within erosion classes. The zero class for the K factors was water bodies and reflected by the water class in the LULC. Spatial distribution of K factors both within and between erosion classes was not significantly different from distributions within the total WEW. This similarity was most likely due to the relatively limited range of K in the database, 0.15 to 0.43, when compared with other factor ranges (Table 4). A varying relationship was noted between slope length and erosion classes. Greatest slope length influence occurred in the 6.2-9.0 Mg/ha erosion class with slope lengths >120 m. Slope length influence decreased in higher erosion classes. Slope also influenced erosion. The lowest erosion class was influenced by the two lower slope classes while higher slope classes dominated middle erosion classes. Slope influence also decreased with higher erosion classes. These factors did not significantly affect the higher erosion classes. Higher erosion classes were mainly affected by LULC. The highest erosion class (> 33.6 Mg/ha) was dominated by lesser quality pastures, transitional areas, cropping areas, scrub brush and poultry operations. In the highest erosion class, these areas had distributions 20 to 50 times greater than total watershed distributions.

These highly erodible areas in the WEW mostly correspond to soil taxonomic units of Clarksville, Cleora, Moko, Noark, Peridge, Razort, Secesh and Summit. Of these soils, Clarksville, Cleora, Noark and Peridge soils cover 20% of the watershed, although not all of these soils occurred in the highest erosion class. Soils that occur in low erosion areas include Arkana, Captina, Johnsburg, Sogn, Linker, Pickwick and Savannah and comprise over 3% of the total watershed. The physical properties and topographic location of these soils are not homogeneous within erosion classes, nor are they unique between erosion classes. The lack of uniformity of the soil properties within these erosion classes suggests that estimated erosion is due to some other parameter, most likely C factors. The spatial distributions of the remaining 75% of the soils in the erosion classes were not significantly different from that of the total watershed.

With the exception of C factors (LULC), all other factors represent natural features of the watershed, which cannot be modified to any extent to reduce erosion potential. However, factor C is a changeable parameter. Through best management practices, erosion can be controlled by encouraging good vegetative growth in poor pasture areas and erosion control methods in bare ground transitional areas.

Phosphorus Index Model

The first PI model simulation on the WEW was made to assess the overall vulnerability of the watershed to P transport without any applied fertilizer. Input parameters were erosion, runoff and soil test P (Fig. 2; Table 5). Nearly 72% of pasture in the WEW was in the low PI vulnerability category, 25.5% was in the medium category and only 2.5% was in the high vulnerability category (Fig. 2; Table 5). These results may reflect the lack of significant influence of STP when no fertilizer P_2O_5 was applied. Although there were input parameters classified as very high PLR, there were no very highly vulnerable areas to P transport according to model simulations. This was possibly due to the relatively low erosion estimates from the USLE, which were subsequently reflected in large spatial distribution of low erosion PLR values. Virtually all areas that had erosion PLR values in the high or very high categories were also estimated to be highly vulnerable to P transport without any fertilizer additions (Fig. 1 and 2).

The distributions of P transport vulnerability for inorganic and organic P_2O_5 fertilizers applied to pastures are presented in Tables 6 and 7, respectively. With a simulated broadcast application of less than 34 kg of inorganic P_2O_5/ha to the pastures, there was a shift in the percentage of the WEW in a PI classification (for example, a 57.4% reduction in spatial coverage in the low PI category, a 53.4% increase in the spatial coverage in the medium PI category and a 4% increase in the high category (Fig. 3; Table 5)). As inorganic P_2O_5 application rate increased, the extent of the pastures in the higher PI category increased dramatically with a particularly large reduction in the low category. A similar response was found with the simulations of organic fertilizer P_2O_5 broadcast to the pastures; i.e., as the application rate of organic P_2O_5 increased, the extent of the more vulnerable areas to P transport increased (Fig. 4; Table 6). This increase was expected due to the log 2 increase between PLR values.

The highest simulated P_2O_5 application rates were intended to overload the pastures with P_2O_5 fertilizer. As a result, the extent in the high PI category of the organic P_2O_5 was almost twice that of the inorganic P_2O_5 fertilizer. This response was mainly due to the difference in weights given in the PI model to inorganic (0.75) and organic (1.00) fertilizers. Not only were the assigned model weights different between the two fertilizer types, but the inorganic fertilizer covered a wider range of application rates than the organic fertilizer, suggesting that additions of organic fertilizer were considered to be more influential on P transport. There was an increase in spatial distribution of the very highly vulnerable category as the P_2O_5 fertilizer application rates increased; however, the change may not be significant when related to the total WEW area. This lack of significant increase was due to a threshold limit within PI classification where the value range assigned to the highly vulnerability category had a much larger range, 16, than ranges of the low and medium vulnerability categories, 8 and 6, respectively (Table 1).

In the areas with high PI indices, invariably the erosion class was greater than 34 Mg/ha/year, the runoff class was very high, and the STP was above 336 kg/ha. As P_2O_5 application rate increased, lower PLR values of erosion, runoff and STP classes were included in the most vulnerable areas. Under conditions of high fertilizer application rates to pastures, numerous combinations of these factors may result in a high PI index for any given area.

CONCLUSIONS

There were areas in the WEW with high erosion rates and areas highly vulnerable to P transport; however, the spatial distribution of these areas was minimal when related to the total watershed area. Calculations indicated that the WEW was not experiencing severe soil erosion. The areas of estimated high sediment losses were only a small percentage of the total watershed area and generally had land cover classification of poor pastures, bare ground or scrub brush and rangeland. The USLE input parameters K and LS are physical features of the landscape and cannot be modified to any extent to limit erosion. However, elements controlling C factors were dominated more by land features that can be modified, such as pasture quality. Modifications to land use and land cover via best management practices could significantly reduce erosion. The use of the USLE in a GIS environment can aid in establishment of best management practices by locating potentially highly erosive areas, determining the factors responsible for the high erosion and estimating the effects of various best management practices.

Results of the PI model simulations showed areas of the WEW that were either highly or very highly vulnerable to P transport. The spatial distribution of these areas depended upon the P fertilizer type and application rate. Even at the highest P fertilizer application rates, there was minimal spatial coverage considered to be very highly vulnerable to P transport due to the relatively large range of the highly vulnerable PI classification. The increase in coverage of the highly vulnerable areas with increasing P fertilizer application was due to the log 2 increases between PLR values. This rapid increase was accentuated with organic fertilizer applications because of the higher weight (1.0) and more limited fertilization application rates. This also was accounted in the differences in the distribution of the very highly vulnerable areas between inorganic and organic fertilizer, 0.1% and 2.1%, respectively.

The PI model could aid in best management practices by allowing fertilizer recommendations to be partly based upon P concentrations in vulnerable areas. The current status of the GIS database for the WEW does not allow this detail since current STP data apply only to soil series and not specific locations. However, with the addition of previously collected STP data by county agricultural extension offices, less hypothetical and more realistic applications of the PI model could be made. Best management practices could greatly benefit from this combination of STP data collection and GIS application.

Results from both the USLE and the PI emphasize that P transport vulnerability can be reduced by controlling potential sediment transport and P fertilizer application. The parameters that are readily changeable with these models are land cover and fertilization management. These two parameters are closely related in that a change in one will result in a change in the other. An increase in vegetative growth of a pasture via fertilization will reduce sediment transport and P transported via the sediment. Monitoring soil test phosphorus would determine what type and how much fertilizer could be use to control the transport of dissolved phosphorus. The combination of the USLE, PI Model and GIS provides a powerful tool for such a task by locating, establishing and implementing best management practices for individual areas within a watershed and applying the potential effects of best management practices to the whole watershed.

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Table 1. Site characteristics, weights and phosphorus (P) loss ratings used in the Phosphorus Index model.

Site Characteristic (weight)	Phosphorus loss rating (value) None (0)	Low (1)	Medium (2)	High (4)	Very High (8)
Soil erosion Mg/ha (1.5)	N/A	< 11.2	11.2 - 22.5	22.5-33.7	> 33.7
Runoff class (0.5)	Negligible	Very Low or low	Medium	High	Very high
Soil P test (1.0)	N/A	Low	Medium	High	Excessive
	Fertilizer Application Rate kg/ha				
Inorganic P_2O_5 (0.75)	None Applied	1 - 34	35-100	100-168	> 168
Organic P_2O_5 (1.0)	None applied	1 - 34	35 - 67	68 - 100	> 100
Application method (1.0)	N/A	N/A	N/A	N/A	Surface applied
		Phosphorus Index Classification			
Phosphorus indices		< 8	8 - 14	15 - 32	> 32
Qualitative Rating		Low	Medium	High	Very High

Table 2. Spatial distribution of Phosphorus Index model input map type parameters.

Category	Area ha	%
Erosion class		
Low	29,702	89.1
Medium	2,492	7.5
High	337	1.0
Very High	770	2.4
Runoff Class		
Negligible	3,116	9.3
Low or Very Low	8,205	24.6
Medium	9,588	28.8
High	8,441	25.4
Very High	3,951	11.9
Soil Test P Class		
Low	1,614	4.9
Medium	3,968	11.9
High	22,654	68.0
Excessive	5,065	15.2

Table 3. Potential erosion in the War Eagle Watershed generated by the USLE from a GIS spatial database.

Potential Erosion Mg/ha	Area ha	%
< 2.24	50,005	57.9
2.24 - 4.48	16,338	18.9
4.48 - 6.72	8,261	9.6
6.72 - 8.96	3,977	4.6
8.96 - 11.2	3,095	3.6
11.2 - 33.6	2,818	3.2
> 33.6	1,946	2.2
Total	86,440	100.0

Table 4. Summation of the USLE input parameters by estimated erosion classes. Bold values are one and one half times more than the total watershed distributions.

	Potential Erosion (Mg/ha)							WEW
Attribute	< 2.2	2.2 - 4.5	4.5 - 6.2	6.2 - 9.0	9.0 - 11.2	11.2 - 33.6	> 33.6	Total
k factor (%)								
0	**1.2**	0.0	0.0	0.0	0.0	0.0	0.0	0.7
0.15	6.1	7.8	8.0	9.0	7.0	4.7	2.7	6.7
0.17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2	20.8	28.9	31.3	28.0	26.3	19.6	14.9	23.7
0.24	15.4	21.5	19.1	18.2	14.9	15.4	18.2	17.1
0.28	21.5	21.3	23.6	24.4	35.5	36.2	30.3	23.0
0.32	23.9	16.9	15.4	16.8	13.3	18.0	23.2	20.8
0.37	6.3	2.1	1.7	2.3	1.8	3.7	6.3	4.6
0.43	4.9	1.5	1.0	1.4	1.2	2.4	4.4	3.5
Slope Length (m)								
30	73.6	44.9	27.0	20.4	21.4	25.9	38.5	57.1
60	19.6	32.8	28.8	23.3	22.4	24.7	28.4	23.6
90	5.1	14.8	**22.8**	**24.0**	**21.1**	**20.4**	**17.2**	10.9
120	1.2	5.1	**12.4**	**15.6**	**14.8**	**12.8**	**8.8**	4.7
> 120	0.5	2.4	**8.8**	**16.6**	**20.2**	**16.2**	**7.1**	3.7
Slope (%)								
0-3	**11.9**	0.4	0.6	1.1	0.7	1.4	0.6	6.0
4-8	**32.9**	4.5	2.0	2.5	3.9	9.2	12.4	20.9
9-13	31.1	15.4	10.2	8.3	4.9	10.3	22.4	24.5
14-20	22.6	**49.3**	36.0	22.4	22.2	22.7	33.5	29.2
> 20	1.5	**30.4**	**51.2**	**65.6**	**68.4**	**56.5**	**31.1**	19.5
LULC								
Pasture								
Good	**38.3**	9.3	3.7	1.7	0.7	0.3	0.1	24.4
Fair	7.5	14.8	**20.4**	**24.7**	**30.9**	**35.4**	9.4	12.7
Woodland	0.0	0.1	0.2	0.2	0.7	**2.8**	**12.0**	0.4
Over Grazed	0.0	0.1	0.1	0.4	**0.9**	**2.5**	**8.5**	0.4
Poor	0.0	0.0	0.0	0.4	0.1	0.5	**18.5**	0.5
Crop	0.1	0.1	0.4	0.7	**1.2**	**4.9**	**13.8**	0.6
Poultry	0.0	0.0	0.1	0.1	**0.5**	**1.5**	**6.0**	0.2
Scrub Brush	0.3	0.8	1.2	**2.9**	**4.2**	**15.6**	**25.2**	1.8
Transitional	0.0	0.0	0.0	0.0	0.0	0.0	**1.9**	0.0
Forest	52.1	74.3	73.3	68.5	60.6	36.2	4.5	57.8
Urban	0.5	0.6	0.4	0.4	0.3	0.2	0.0	0.5
Water	**1.2**	0.0	0.0	0.0	0.0	0.0	0.0	0.7

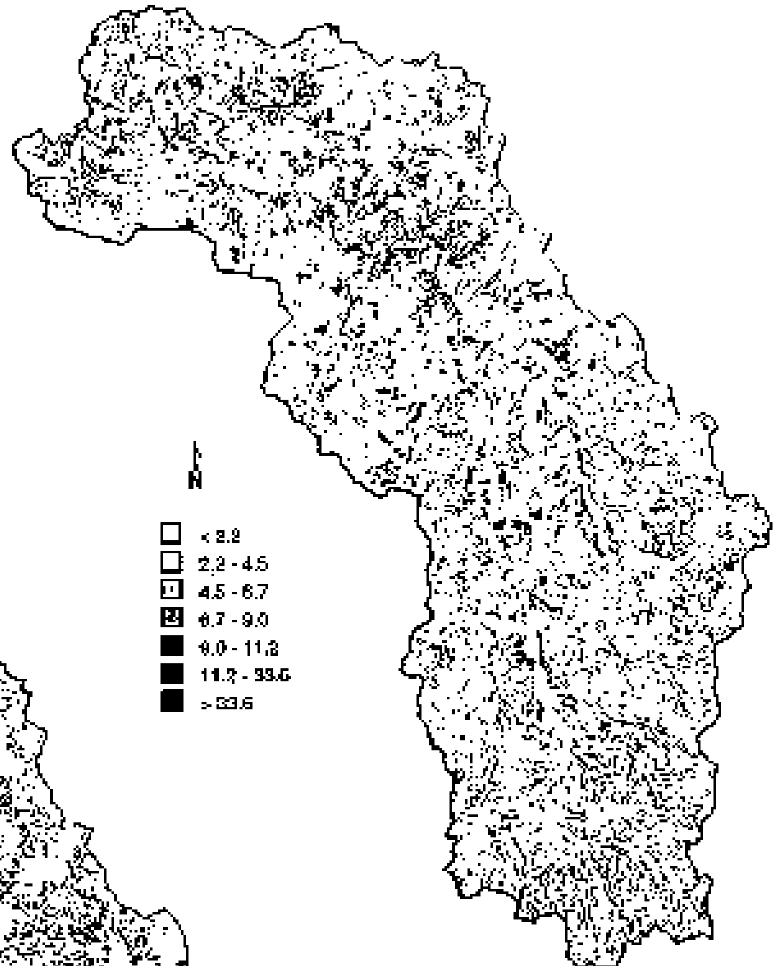
Table. 5. Distribution of phosphorus (P) transport vulernability calculated by P application rate for inorganic P fertilizer applied to pastures only. Areas do not include water bodies (30 ha).

P_2O_5 Application Rate	P Transport Vulnerability	Area ha	%
Kg/ha			
0	Low	23,973	71.9
	Medium	8,507	25.6
	High	821	2.5
1-34	Low	4,807	14.5
	Medium	26,329	79.0
	High	2,165	6.5
35-101	Low	2,102	6.4
	Medium	28,335	85.0
	High	2,864	8.6
102-168	Low	51	0.2
	Medium	28,170	84.5
	High	5,080	15.3
> 168	Medium	17,059	51.2
	High	16,215	48.7
	Very High	27	0.1

Table. 6. Distribution of phosphorus (P) transport vulnerability calculated by P application rate for organic P fertilizer applied to pastures only. Areas do not include water bodies (30 ha).

P_2O_5 Application Rate	P Transport Vulnerability	Area ha	%
Kg/ha			
0	Low	23,973	71.9
	Medium	8,507	25.6
	High	821	2.5
1-34	Medium	9,269	18.9
	High	27,005	81.0
	Very High	27	0.1
35-67	Medium	4,787	14.4
	High	28,481	85.5
	Very High	33	0.1
67-101	Medium	51	0.2
	High	33,088	99.3
	Very High	162	0.5
>101	High	32,632	97.9
	Very High	669	2.1

Fig. 1. Estimated annual erosion from the Universal Soil Loss Equation. Potential yields are given in Mg/ha/year.



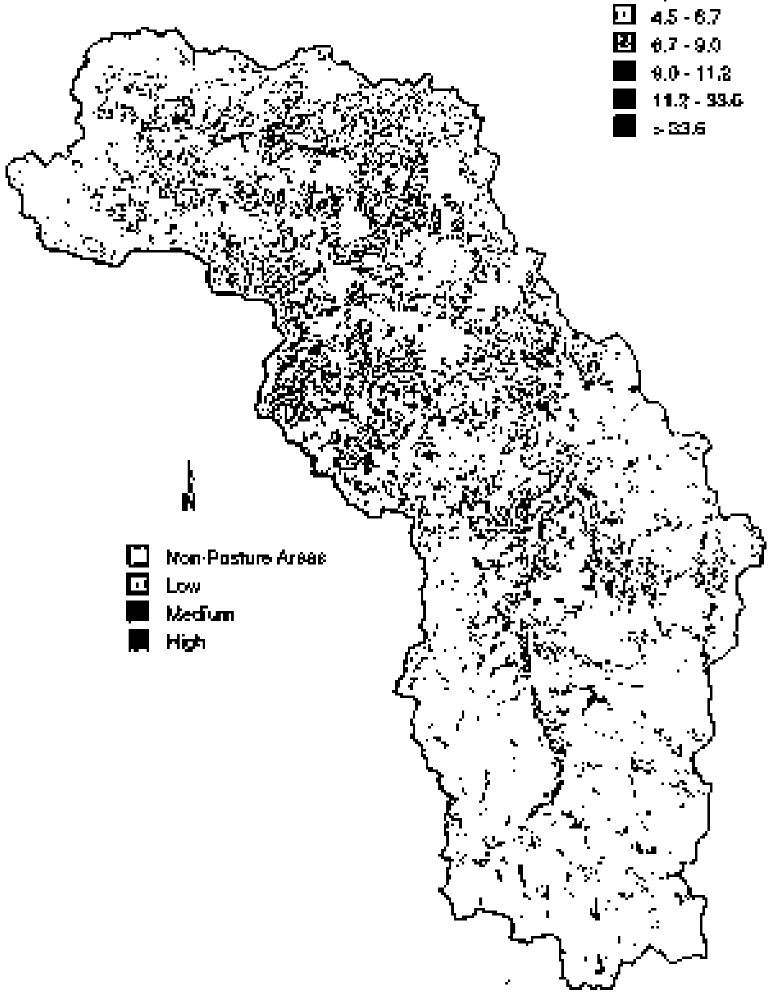
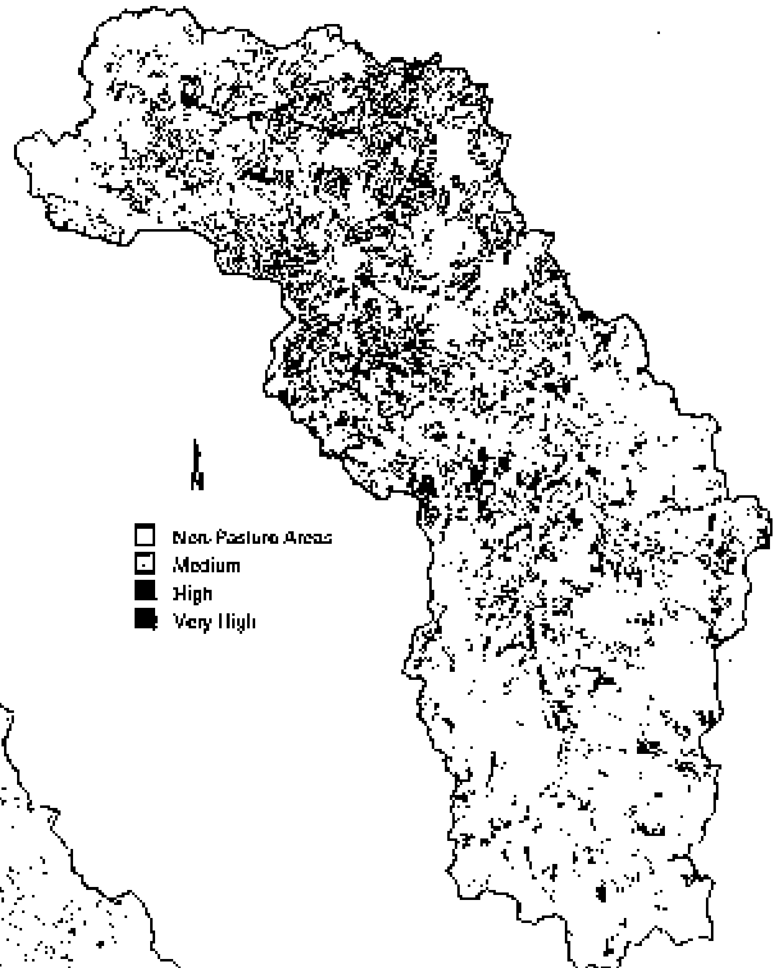


Fig. 2. Spatial distribution of areas vulnerable to P transport without any fertilizer applied. Non-pasture areas were excluded from the PI calculations.

Fig. 3. Spatial distribution of areas vulnerable to P transport with inorganic P_2O_5 fertilizer at a rate of > 168 kg/ha. Non-pasture areas were excluded from the PI calculations.



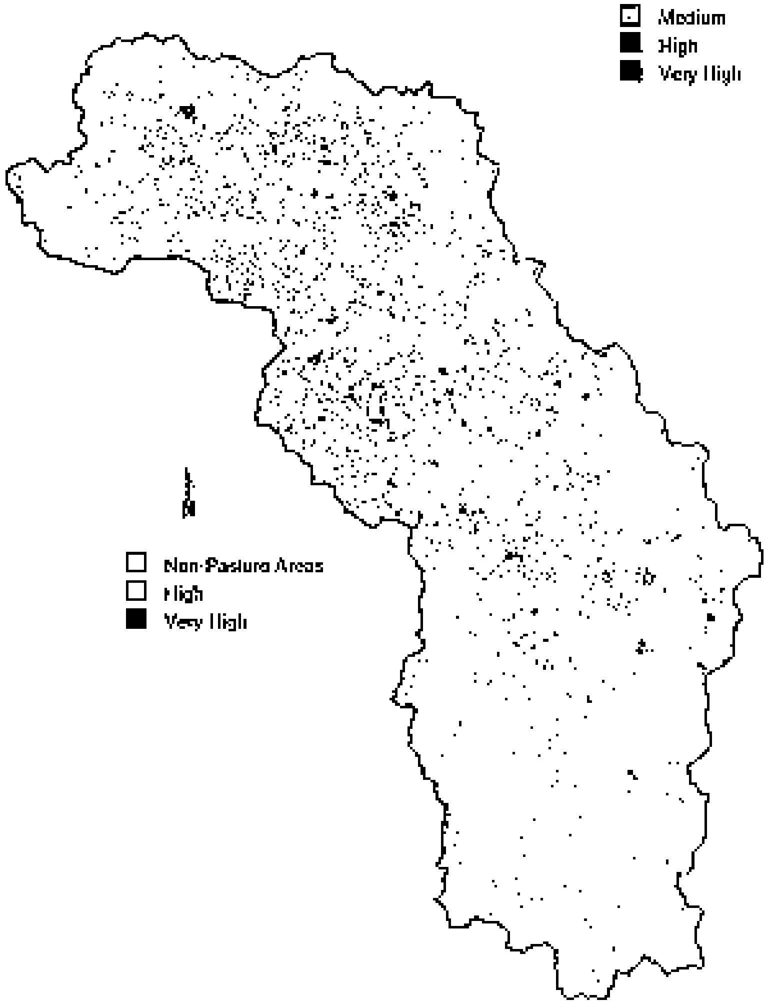


Fig. 4. Spatial distribution of areas vulnerable to P transport with organic P_2O_5 fertilizer at a rate of > 100 kg/ha. Non-pasture areas were excluded from the PI calculations.

KEYS TO SUCCESSFUL PRODUCTION OF TRANSPLANTED CROPS IN HIGH-RESIDUE, NO-TILL FARMING SYSTEMS

Ronald Morse[1]

INTRODUCTION

The Relationship Between Tillage and Soil Quality

Reducing or minimizing tillage (particularly inversion of the soil, using the moldboard plow, disk, etc.) increases soil organic matter content, which in turn increases soil quality (Ismail et al., 1994; Doran and Jones, 1996). From the perspective of both the farmer and the soil scientist, in-situ production and retaining high levels of crop residues (high-residue farming) on untilled soil (no-tillage) is the most cost- and time-efficient way of increasing soil organic matter (Crovetto, 1996). Indeed, high-residue/no-till (HR/NT) farming systems can play a major role in achieving a sustainable agriculture worldwide (Lal et al., 1990).

The Advantage of Using Transplants in HR/NT Systems

High-residue covers can interfere with seed germination and seedling growth, lowering the chance of achieving adequate plant survival and stand with direct-seeded crops. Conversely, proper establishment of large, vigorous transplants minimizes crop interference and dramatically increases the chance of plant survival in high-residue covers. In addition, using transplants favors rapid canopy closure and weed suppression, reducing the need for chemical weed control (Morse, 1995).

No-till Equipment: A Limiting Factor

For many decades, home gardeners and small-scale farmers have applied organic mulches to conserve their soil and water resources, improve weed and pest control, and increase yield and quality of vegetable crops (Dutton, 1957). No-tillage systems (using *in-situ* mulches) have all the advantages of using applied mulch, without disturbing the soil and requiring the time-consuming and often uneconomical practice of purchasing, hauling and applying straw and organic waste materials.

If organic mulches are such a valuable resource, why are HR/NT systems not widely practiced in the United States and other areas of the world? Until recently, a major problem slowing adoption of no-till systems has been lack of available equipment. However, during the past five years, equipment and associated technology have been developed and are commercially available for small-scale farm production of transplanted crops in HR/NT systems (Morse et al., 1993). This paper will attempt to briefly outline and summarize key components of HR/NT systems that have been tested and used successfully by farmers in many areas of the United States in the 1990s.

NO-TILL TRANSPLANTED CROPS IN THE 1990S–KEYS TO SUCCESS

High, profitable yields are achievable using HR/NT production systems. Growers should use a year-round systems approach in HR/NT farming. Success depends on 1) selecting the most sustainable or appropriate crops, cultivars, soils and micro climatic conditions and 2) identifying and applying yield-enhancing practices inherent or specific for HR/NT systems. This paper will focus on the latter: yield-enhancing practices specific for HR/NT systems. In the sections that follow, four production strategies (objectives) are briefly presented, emphasizing proper use of available equipment and associated technology. These four objectives are explained more extensively in Morse et al., 1998.

Objective I: Produce a dense, uniformly distributed cover crop prior to transplanting

Sparse, unevenly distributed surface coverage is a major cause of poor results in NT transplanted crops. In contrast, establishing a dense, uniformly distributed cover crop prior to transplanting provides the greatest chance for success. Benefits from heavy, evenly distributed residues include weed suppression, reducing or even eliminating the need for preemergent herbicides; greater conservation of both soil and water; and greater trafficability resulting in improved flexibility in timing field operations.

With NT production systems, investing in cover crop residues prior to transplanting is like establishing a savings account: you receive the input (deposit) back plus interest later. Every effort and expense to establish a relatively weed-free, dense cover crop will be rewarded later in the form of improved crop yields and quality. Recommended cultural practices include selecting the most adaptive and compatible cover crops, obtaining a uniform dense stand by drilling high seed rates at close between-row spacing and providing adequate growth inputs (water, lime and fertilizer) and growing time to maximize cover crop biomass.

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Objective II: Kill cover crops prior to transplanting, leaving a heavy, uniformly distributed mulch cover over the soil surface

Weeds reduce crop yields predominantly by interspecific (weed-crop) competition for water, nutrients and light. To minimize interspecific competition, the cover crop must be killed and subsequently managed in such a manner that the *in situ* mulch effectively covers and shades the soil surface but does not excessively shade or compete with transplanted crops for light, nutrients and water. Either chemical and/or mechanical methods can be used to kill and generate a dense mulch (Dabney et al., 1991; Morse, 1995).

Chemical methods. Contact herbicides such as glyphosate (Roundup) and paraquat (Gramoxone Extra) are needed to desiccate perennial and immature annual weed and cover crop species. Desiccation should be done two to five weeks prior to transplanting to ensure complete vegetative kill. Glyphosate should be applied at least four weeks prior to transplanting to avoid any potential stunting of the transplanted crops from root-to-root transfer of active glyphosate exuded from roots of the treated cover crop to the roots of the transplanted crops. Often two or more sprays are required to completely desiccate all vegetation.

Mechanical methods. Many species of mature annual grass and legume cover crops can be effectively killed using mechanical methods (Morse, 1995). To be successful, however, mechanical treatments must occur after the annual species have developed beyond their vegetative stage and ideally after flowering. When attempting to kill mixtures of annual species (both cover crops and/or weeds) mechanically, all species should be mature and incapable of regrowth following mechanical treatments. Mechanically killing cover crops has two distinct advantages over using contact herbicides: 1) because herbicides are not used, negative environmental impacts are reduced; and 2) cover crops can be killed just before planting, which maximizes the growth potential and maturation of the residues. Since a relatively high percentage of transplanted crops are irrigated, potential soil moisture depletion problems from drought prior to planting are negated.

Flail mowing and rolling have been used effectively to kill black oat (*Avena strigosa* Schreb.), cereal rye (*Secale cereale* L.), wheat (*Triticum aestivum* L.), foxtail millet (*Setaria italica* L.), buckwheat (*Fagopyrum saggitatum* Grlib.), crimson clover (*Trifolium incarnatum* L.) and soybean (*Glycine max* L.). Flail mowing effectively kills most mature annual cover crops and distributes a uniform layer of organic mulch over the soil surface. Rotary mowers are not recommended because they tend to windrow the chopped residues. Flail mowers contain many small double-edged knives affixed to a parallel rotor that uniformly distribute the finely cut residues over the soil surface.

Rolling can effectively kill many cereal grain crops and some legumes. Cover crop kill is often less complete when rolled than when mowed. However, the NT transplanters function better, and after transplanting cover crop persistence and weed suppression are better in rolled than in mowed plots.

When rolled effectively, dense stands of mature annual cover crops are laid prostrate uniformly over the ground and remain lodged. Complete kill takes from a few days to several weeks, and in some cases partial greening may remain throughout the growing season of the transplanted crop. With most crops, however, any interspecific competition between the transplanted crop and the living cover is not a serious yield-limiting factor and is more than compensated by the many growth-promoting benefits of rolled, heavy crop residue mulch. Planting the transplanted crops in multiple rows often helps considerably to minimize greening of the rolled cover crops and thus reduces interspecific competition effects.

Many types of equipment have been used to roll mature annual cover crops, including:

1. *Disengaged flail mower.* When disengaged and pulled over the ground, the roller gauge wheel of the flail mower can effectively flatten mature crop residues.
2. *Grain drills*. Modified grain drills equipped with coulters and cast-iron press wheels spaced 5 in. apart have been effectively used to roll some cover crops.
3. *Turf or construction rollers*. Commercially available water-filled rollers used for compacting and rolling turf and roadways could be used to roll crop residues.
4. *Roller-crimper drum.* Water-filled drum rollers modified with horizontal welded blunt steel blades or metal strips have been used in Brazil and other locations to roll-crimp cover crops, thus facilitating killing yet leaving plant stems intact.
5. *Undercutter-roller*. A modified blade plow (V-plow sweep) has been used as an undercutter, designed to sever the cover crop roots, followed by a rolling harrow which rolls the residues flat over the ground. This undercutter-roller functions well on raised beds under dry, non-rocky conditions.
6. *Rolling stalk chopper*. When properly adjusted or modified, stalk choppers can effectively roll and evenly distribute high-residue cover crops.

Rolling appears to have considerable merit for mechanically killing cover crops. Ongoing crop residue management research and field testing in several states (Virginia, North Carolina, Pennsylvania, Alabama, Maryland and California) should help clarify the relative advantages and specific uses of different rolling methods for mechanically killing cover crops in HR/NT vegetable production systems.

Chemical/mechanical methods. In some situations where contact herbicides are required to achieve an adequate kill, mowing or rolling may be used to minimize shading of the transplanted crop. For example, contact herbicides combined with or without pre-emergent herbicides can be used to desiccate tall-standing, dense residues, followed by mowing or rolling prior to transplanting or mowing (with mower blades held above the established transplants) after transplanting. With sparse, low-growing cover crops, mechanical methods would not be needed.

The Subsurface Tiller-Transplanter (SST-T - Objective III) functions best in upright standing (intact) residues, regardless of the height of the cover crops. In contrast, in some situations the SST-T functions poorly in lodged desiccated residues or coarsely chopped, unevenly distributed residues such as derived from rotary mowers.

Recently, several cover crops have been effectively killed by rolling first followed by applying paraquat. This method looks very promising since rolling can optimally orient and distribute flattened residues, which facilitates transplanting effectiveness with the SST-T.

Objective III: Establish transplants into cover crops with minimum disturbance of surface residues and surface soil

Lack of reliable NT transplanters and inconsistent stand establishment have been major factors limiting the adoption of NT systems for transplanted crops. Generally, low yields occur when no-tillage is practiced in poorly drained, compacted soils. In NT systems, when a device (chisel plow, coulter, rototiller, undercutter, etc.) is used to loosen or fracture a strip of in-row soil prior to transplanting, both stand establishment and subsequent plant growth are improved, approaching or even surpassing that achieved in tilled soils. With the recent development of the Subsurface Tiller-Transplanter (SST-T), no-tillage with in-row soil loosening and transplanting are combined in one pass across the field. The SST-T is a "hybrid," combining subsurface soil loosening to alleviate soil compaction and effective setting transplants–in one operation with minimum disturbance of surface residues or surface soil.

The SST-T has an upright, high-clearance design with a double-disk shoe similar to that of earlier custom-made models used in the 1970s. However, in addition, the SST-T has a unique subsurface tiller (SST) aligned in front of the double-disk shoe of the transplanter. The conceptual design and functioning of the SST-T is uniquely different from that of earlier and present-day NT transplanters. With some NT models, the cultivator-type shoe performs both the tilling and the planting functions. Under compacted, rocky conditions, the rigid-mounted shoe is easily bent or broken, which seriously reduces its usefulness for NT systems. In contrast, the spring-loaded soil-loosening component of the SST has heavy-duty construction and subsurface tills a narrow strip of soil ahead of the double disk shoe of the transplanter. The double-disk shoe moves through the residues and tilled strip with relatively little resistance and with minimal surface soil and surface residue disturbance. The SST-T is an efficient (less equipment breakdown) and effective (less transplant resetting needed) NT transplanter that, when used in heavy residues, maximizes soil and water conservation and early field reentry permitting planting, spraying and harvesting operations to be done within a few hours following irrigation or rainfall.

The single coulter and/or double-disk shoe of other NT models often do not loosen enough in-row soil for optimum root-soil contact, resulting in reduced plant survival and slow early growth of the improperly set transplants. Fluted or ripple coulters can loosen more in-row soil than the smooth coulters; however, they do not cut the residues as effectively as the smooth coulter and may cause hair pinning (pressing of the residues into the soil without cutting).

The SST-T is also equipped for precision placement of 1) liquid starter fertilizer-pesticide solutions around the root system of the transplant, 2) liquid or granular fertilizers underneath the transplant and 3) granular fertilizers surface applied in bands on both or either side of the transplant row. A combination of these treatments is expected to eventually give the most efficient use of soil amendments. Also, a drip layer attachment became available in 1997. This attachment places drip tubing at varying depths below the crop residues and in close proximity of the crop row.

Objective IV: Practice year-round weed control

The old adage "an ounce of prevention is worth a pound of cure" is particularly valid in HR/NT farming. Weed control can be achieved two ways--directly using both chemical and mechanical means and indirectly by using cultural practices that promote rapid plant growth and canopy closure. Preemergence and post-emergence herbicides can be applied and, in conjunction with physical and allelopathic effects associated with high-residue covers, often provide adequate weed control. However, the best direct method is to lower weed and seed populations prior to transplanting (i.e., apply aggressive weed-control measures prior to and/or during production of the cover crop).

Of critical importance, NT fields should not have a serious perennial weed problem such as nutsedge, quackgrass, Johnsongrass or morning glory. Weedy fields should be cleaned up prior to seeding the cover crop; and/

or, if necessary, herbicides should be used in conjunction with production of the cover to minimize weed population prior to transplanting. Appropriate use and timing of pretransplant herbicides to achieve a "stale seedbed" (reduced weed seed population) and a dense weed-free cover crop are generally an inexpensive, more environmentally friendly use of herbicides than if applied later in conjunction with production of the transplanted crop.

The term "stale seedbed" (more appropriately stale transplant bed) refers to techniques allowing weed seeds in the soil surface to germinate and be killed without redisturbing the soil other than the seeding operation. Fallowing the NT field prior to seeding the cover crop and eradicating emerged weeds, either by mowing or with herbicides, followed by NT drilling cover crops is an excellent way of obtaining both a stale seedbed and a weed-free cover crop prior to transplanting.

Using cultural practices that promote rapid plant growth and canopy closure will result in improved weed suppression and higher crop yields. Recommended cultural practices include 1) using large, vigorous transplants; 2) arrangement of plants in multiple rows; and 3) precision placement and timing of fertilizer and water.

FUTURE NEEDS–2000 AND BEYOND

Strengthen competitive position of small farms in American agriculture

A recent report from the USDA National Commission on Small Farms emphasized adoption of sustainable agriculture as a profitable, ecological and socially sound strategy for small farms (USDA, 1998). Availability of affordable and effective small-scale, no-till equipment is essential to expedite adoption of no-tillage, especially HR/NT farming systems. Farmers and researchers must continue to refine and develop no-till equipment for mechanically killing high-residue cover crops, plant establishment (both direct seeding and transplanting) and harvesting.

Develop HR/NT systems for organic farmers

Historically organic farmers have avoided NR/NT systems because mechanical weed control is generally complicated by surface residues. Paradoxically, primary tillage and weed implements used by organic farmers incorporate surface residue, excessively aerate the soil and reduce soil organic matter content and soil quality. Research is urgently needed to evaluate utilization of legume-grass mixtures and injectable (liquid, granular, pelleted, etc.) organic fertilizers in HR/NT systems for production of organic vegetables.

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EFFECT OF TILLAGE ON *SENNA OBTUSIFOLIA* AND *XANTHIUM STRUMARIUM* POPULATION, INTERFERENCE AND SEED BANK

L.R. Oliver and M.T. Barapour[1]

SUMMARY

Two of the most troublesome weeds in the southern United States are *Senna obtusifolia* and *Xanthium strumarium*. A field experiment was conducted to determine the influence of tillage practice and interference level on seed production potential, emergence pattern and soil seed bank of *S. obtusifolia* and *X. strumarium* and to determine the dominant species after introduction into a weed-free field. Interference level did not influence the soil seed bank except for *S. obtusifolia* under tilled conditions. Under tilled conditions, *X. strumarium* was the dominant species, and *S. obtusifolia* was dominant under no-till conditions. Soil seed bank loss was greater for both species with tillage. Three years after initial seed deposition, the remaining *S. obtusifolia* seeds were 100% viable while *X. strumarium* burs were not viable. Thus, under no-till conditions, the *X. strumarium* soil seed bank was depleted while *S. obtusifolia* was not.

INTRODUCTION

Senna obtusifolia L. and *Xanthium strumarium* L. are among the most troublesome weeds in many fields of the southern United States (Elmore, 1986). Once the weeds are introduced and established, a producer is confronted with the potential for a severe weed problem for many years. *X. strumarium* is more competitive than *S. obtusifolia* (Monks and Oliver, 1988); however, other factors may regulate the population and determine the dominant weed species when both species are established on an equal basis.

The lifespan of weed seed in soil is important since potential weed problems exist as long as weed seed remain viable (Egley and Chandler, 1978). An understanding of seed bank function requires knowledge of the numbers of seed present at a given time and knowledge of the soil seed bank dynamics. Seed bank dynamics are affected by both rate of input (direct deposit by the plant and by dispersal from humans, wind, rain, birds and other animals) and rate of output (loss through germination, deep burial, predation, disease and death) (Fenner, 1985). Understanding emergence patterns and extent of seedling emergence from the seed bank aids in weed control and estimation of crop yield loss.

Soil tillage reduces the number of weeds but may increase germination of weed seed in the soil seed bank (Roberts and Neilson, 1981). In contrast, no-till systems typically have high populations of small-seeded annual weeds. The objectives of the present work were 1) to determine the influence of tillage practice and interference level on seed production potential, emergence pattern and soil seed bank of *X. strumarium* and *S. obtusifolia* and 2) to determine the dominant species after initial introduction into a previously weed-free field.

Materials and Methods

A field study was conducted at the Main Agricultural Experiment Station, Fayetteville, Arkansas, from 1991 through 1994. The experimental design was a split-plot with a three by two factorial of subplots and four replications. Main plots were no-till and tilled. Tilled plots were tilled 10 to 12 cm deep each year following actual or anticipated seed production in mid-November and in early April prior to weed emergence with a Triple-K seedbed cultivator with rear rolling baskets. The factorial subplots were three weed populations: *S. obtusifolia* alone, *X. strumarium* alone and *S. obtusifolia* plus *X. strumarium*; and two seed deposition levels: harvested in the year of establishment (1991) for initial seed production determinations or allowed to produce seed and deposit to the soil for one year (1991). Each plot was 5 m^2 with a 1-m border between plots. The soil was a Taloka silt loam (fine, mixed, thermic Mollic albaqualfs) with 25% sand, 62% silt, 13% clay, 1% organic matter and a pH of 6.7.

Initial Seed Production Determination.

In the year of establishment (1991), each plot consisted of four single-seed-source weed seedlings transplanted 2 May 1991 and allowed to grow to maturity and deposit seed. The distance between plants was 2 m. Plots with *S. obtusifolia* plus *X. strumarium* had two seedlings of each species planted alternately in the plot. All plants received the same cultural practices and were protected from wind breakage by staking, allowing plants to grow and produce seed as uniformly as possible.

At the end of the growing season, plants were harvested for seed or bur production. *X. strumarium* burs were counted for each plant. *S. obtusifolia* pod length was measured, and number of seeds per pod was determined by the following linear equation:

$$Y = -0.0329 + 1.766 X, r^2 = 95$$

[1]Department of Agronomy, University of Arkansas, Fayetteville, Arkansas. Previously published, Second Annual Weed Control Congress, Copenhagen 1996. pp. 241-246.

where Y = number of *S. obtusifolia* seed in each pod, and X = pod length in cm. Bur or pod counts and lengths were determined in the field in all plots not harvested the first year.

Seed Production for One Year

In 1992, all seedlings were allowed to grow to maturity. Two 0.5- by 0.5-m permanently positioned sub-sample markers were placed in each plot. From the subsamples, the number of emerged seedlings and seedling mortality were recorded every two weeks during the growing season. At the end of the season, entire plot seed production was determined for one set of seed deposition plots while the other set was left undisturbed. For *S. obtusifolia*, number of pods per plot was counted. For both weed species, all plants were cut at the soil line for shoot fresh and dry weights (data not shown). Four 1,000-g subsamples for each species were air dried at 45 C for eight days. *S. obtusifolia* pods were separated from the plants and counted, and average pod length was determined. The number of seeds per pod was calculated from the equation developed in 1991 and was multiplied by the actual pod count to estimate total *S. obtusifolia* seed production per plot. Plants in each plot were harvested at the end of the season for fresh weights (data not shown). *X. strumarium* burs were separated from the subsample before drying. The total bur production per plot was calculated by counting the burs per subsample and multiplying by the total dry weight. In 1993 and 1994, all emerged seedlings were counted and removed every two weeks during the growing season.

Soil Seed Bank Sampling

In November 1994, three years after initial seed deposition, soil samples were taken to estimate *S. obtusifolia* and *X. strumarium* soil seed bank numbers. Each 5-m^2 plot was divided into 25 1-m grids, and 25 soil samples were taken from the upper right corner of each grid with a 10.5-cm-diameter soil probe at a 20-cm depth. Each soil sample was passed through a descending series of sieves with screen sizes of 4.75 mm to collect *X. strumarium* burs, 2.0 mm for *S. obtusifolia* seed and 1.0 mm for escaped *S. obtusifolia* seeds. Water was run through the screens to enhance sample movement. Seeds or burs were separated and counted according to species as an estimate of number remaining in the soil.

General Procedures

During the experiment, unwanted weeds were removed by spraying sethoxydim (Poast-Plus™, 120 g ai/L, BASF) at 0.22 kg ai/ha plus 1% v/v crop oil for grass control. Hand hoeing in tilled plots and hand clipping in no-till plots were used for broadleaf weed control. Glyphosate (Roundup™, 360g ae/L, Monsanto) at 0.84 kg ae/ha was sprayed after each seedling count in 1993 and 1994 to control existing vegetation.

Data were subjected to analysis of variance. Means were separated by Least Significant Differences (LSD) at the 5% level of probability.

RESULTS

S. obtusifolia and *X. strumarium* initiated flowering 1 July and 3 September, respectively, in 1991. At the end of the first season, *S. obtusifolia* produced an average of 11,420 seeds/plant, and *X. strumarium* produced an average of 4,469 burs or 8,938 seeds (achenes)/plant. For the remainder of the paper, *X. strumarium* reproductive potential will be presented as achene number.

Seed production data were similar for intraspecific and interspecific interference levels except for the number of seeds deposited to the seed bank. With intraspecific interference, 1,827 and 1,430 seeds/m^2 were deposited for *S. obtusifolia* and *X. strumarium*, respectively, and only half that amount with interspecific interference. Thus, interference data were combined and averaged in order to present seed production potential.

In 1992 *X. strumarium* seedlings began emerging by the end of May and ceased at the end of June, eight weeks after emergence (WAE) while *S. obtusifolia* seedling emergence began at the same time but continued until August (16 WAE). Similar emergence was noted in 1993 and 1994. *X. strumarium* was larger than *S. obtusifolia* under both tilled and no-tilled conditions (data not shown).

During the growing season, seedling mortality was 9.3% of the population for *X. strumarium* under tilled conditions (data not shown). *S. obtusifolia* seedling mortality varied with interference level. Seedling mortality was 5.6% with intraspecific interference and 17% with interspecific interference. The increase was due to the dominance of *X. strumarium* in interspecific plots because of initial rapid emergence and plant size under tilled conditions. *S. obtusifolia* and *X. strumarium* seedling mortality was not observed in no-till plots due to low plant populations and lack of interference.

By the end of the growing season, 165 and 202 seedlings/m^2 emerged for *X. strumarium* and *S. obtusifolia*, respectively, under tilled conditions, while under no-till conditions only 10 and 29 seedlings/m^2 emerged for *X. strumarium* and *S. obtusifolia*, respectively (Table 1). For both species, approximately 15% of the initial soil seed bank emerged under tilled conditions. Under no-till conditions only 0.2 and 0.08% of the *S. obtusifolia* and *X. strumarium* had emerged, respectively.

In 1992, *X. strumarium* bur production was reduced 42%, and *S. obtusifolia* seed production was reduced 78% under no-till intraspecific conditions compared to tilled conditions (Table 2). Under interspecific, no-till conditions, *X. strumarium* bur production was reduced 46%, but *S. obtusifolia* seed production increased 40%. The reduction in *X. strumarium* interference allowed the remaining *S. obtusifolia* plants to grow larger and produce more seeds than in tilled plots, where *S. obtusifolia* seed production was decreased by *X. strumarium* interference. Thus, no-till significantly reduced *X. strumarium* emergence and seed production potential while increasing potential of *S. obtusifolia*.

In 1993 *S. obtusifolia* seedling emergence was similar under both tillage conditions while *X. strumarium* seedling emergence continued to decline under no-till conditions (Table 1). Percent emergence from the seed bank increased the second year after initial seed deposition to approximately 19% for both species under tilled conditions. However, under no-till conditions *X. strumarium* emergence declined to only 0.03% while *S. obtusifolia* emergence increased to 14%, from 0.2% the previous year. The equivalent seedling emergence for *S. obtusifolia* under both tillage conditions indicates that once a soil seed bank reaches a certain level, only a given number of seeds will emerge due to the number of safe sites (Harper, 1977).

In 1994, the loss of *S. obtusifolia* seed through emergence under no-till was two times greater than under tilled conditions (Table 1). Thus, the initial delay in seed emergence under no-till conditions was being corrected by seeds getting better soil-seed contact, allowing germination of readily germinable seeds. Emergence of *X. strumarium* was negligible regardless of tillage. Not allowing *X. strumarium* to reseed following initial seed production resulted in 29% emergence over a three-year period under tilled conditions; however, only 1% germinated under no-till conditions. *S. obtusifolia* emergence (34%) over the three years was similar to that of *X. strumarium* under tilled conditions; however, under no-till conditions, 24% of the *S. obtusifolia* seed emerged. *S. obtusifolia* seeds were still showing a strong emergence pattern in 1994, indicating that *S. obtusifolia* has a harder seed coat than *X. strumarium*.

The estimated *S. obtusifolia* seed remaining in the soil after three years was 906 and 1,042 seeds per m^2 under tilled and no-tilled conditions, respectively (Table 1), or by soil sampling 54 and 72% of the estimated seed bank under tilled and no-tilled conditions, respectively. Germination tests indicated that 100% of these seeds were viable and would germinate. Seed loss averaged 46 and 28% under tilled and no-tilled conditions, respectively. The estimated number of *X. strumarium* achenes remaining in the soil averaged 756 and 1,058 achenes per m^2 under tilled and no-tilled conditions, respectively (Table 1). Under intraspecific conditions, seed reserve in the soil estimated by soil sampling was 65 and 93% of the achenes remaining under tilled or no-tilled conditions, or a 35 and 7% loss, respectively. Under interspecific interference, there was only a 10 and 5% bur loss under tilled and no-tilled conditions, respectively (data not shown). The increased loss under intraspecific conditions was probably due to more immature seeds being produced under high densities in tilled plots and greater moisture stress in no-till. None of the remaining achenes were viable.

DISCUSSION

The loss of seeds and burs was due to decay, predation, dispersal, immature seed, mechanical destruction and sampling error (Ball and Miller, 1989; Fenner, 1985; Kremer and Spencer, 1989). The higher loss under tilled conditions indicates that microbial decay and insect predation increase with greater soil seed contact.

Emergence potential is critical in terms of competitiveness because the species emerging first has the potential to dominate throughout the season. A high percent emergence early in the season is also an advantage in terms of colonizing an area ahead of other competitors. The dominance of *X. strumarium* over *S. obtusifolia* under conventional tillage is due to the following: 1) tillage creates an adequate seedbed for both species, but *X. strumarium* grows faster than *S. obtusifolia* and shades *S. obtusifolia* plants earlier, reducing *S. obtusifolia* growth and emergence; 2) the dispersal ability of *X. strumarium* is much greater than that of *S. obtusifolia*, so *X. strumarium* can invade the *S. obtusifolia* area; 3) *X. strumarium* has a longer vegetative growth period than *S. obtusifolia*, allowing a longer competitive period; and 4) *X. strumarium* seedling emergence is greater than that of *S. obtusifolia* during the first emergence flush. However, a large number of *S. obtusifolia* seed remained in the soil from initial seed production. So, if *X. strumarium* is controlled, *S. obtusifolia* seeds that remain in the soil profile will have a chance to emerge and cause a new weed problem for the producer.

S. obtusifolia was as competitive as *X. strumarium* under no-till conditions. In 1992, it was expected that *S. obtusifolia* would be the dominant species within the next one or two years under no-till conditions, and 1993 and 1994 results verified that observation. In fact, *S. obtusifolia* became the dominant species because *X. strumarium* burs needed adequate soil-seed contact for germination. The bur prickles prevented soil-seed contact under no-till conditions. In contrast, *S. obtusifolia* seed is smaller and has a smooth, waxy surface for better soil contact and can penetrate soil cracks for improved germination. Thus, the *S. obtusifolia* plant population increased over the years, while the *X. strumarium* plant population was reduced under no-till.

Seed viability and germination tests indicated that the *X. strumarium* soil seed bank was reduced tremendously one to three years after initial seed deposition and remaining *X. strumarium* achenes were very sensitive to decay in or on the soil surface. The loss of viability results in a quick depletion of the *X. strumarium* soil seed bank. The *S. obtusifolia* soil seed bank was not depleted after three years. *S. obtusifolia* seeds have hard seed coats and are more resistant to decay than *X. strumarium* burs in or on the soil surface. Thus, *S. obtusifolia* can pose a more serious problem than *X. strumarium*, especially as no-till practices are adopted.

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Table 1. Effect of tillage on *X. strumarium* and *S. obtusifolia* seed bank potential after four years averaged over interference level.

Species	Tillage level	Initial seed deposition	Plants 1992	Seedlings 1993	Seedlings 1994	Seeds remaining
		---------no/m^2---------				
X. strumarium		1,072				
	Till		165	150	1	756
	No-till		10	4	1	1,058
S. obtusifolia		1,370				
	Till		202	219	44	906
	No-till		29	194	105	1,042
LSD(5%)			100	120	50	250

Table 2. Effect of tillage on *X. strumarium* and *S. obtusifolia* seed production in 1992 (LSD1-to compare species or interference levels at same tillage level and LSD2-to compare same species or interference at different tillage levels).

Species	Tillage level	Interference level Intraspecific	Interference level Interspecific
		---------no./m^2--------	
X. strumarium	Till	880	780
	No-till	510	420
S. obtusifolia	Till	8,940	920
	No-till	1,930	1,290
LSD 1 (5%) 1,800 and LSD 2 (5%) 2,000			

THE ROLE OF INDUSTRY IN CONSERVATION TILLAGE AND SUSTAINABLE AGRICULTURE

Robert G. Palmer[1]

INTRODUCTION

Change in the agricultural arena–as in electronics, computers, etc.–has been rampant the past few years. Change has closed many doors and opened numerous others, especially in the past 10 years. Public sector budgets have been scrutinized and have gone under the knife (in some cases, maybe we should say the ax). Support for traditional programs such as the Cooperative Extension Service and applied research has dwindled.

Industry in now picking up many of the responsibilities once filled by university extension. Pioneer Hi-Bred, Inc., has had an Agronomy Service group for about 30 years in the Corn Belt. Here in the South we have had an Agronomy Service group for less than 10 years. Farmers and dealers call on our agronomists at an increasing frequency as they seek answers to all kinds of crop production questions. I'm sure that other industries have seen the same increase in demand on their technical service staff.

What does all this mean? To agriculture? To farmers? To consumers? To all of us? I don't have all the answers to these questions. However, I may have some of the answers.

As we look at the role of industry in conservation tillage and sustainable agriculture, I will highlight only a few key points. Long-term soil productivity is dependent to a large extent on soil conservation. Soil conservation, in turn, is dependent upon various kinds of conservation tillage, including no-tillage. Conservation tillage is here to stay, and sustainable agriculture is what we are all about. We are told the world population will reach about 8 billion around the middle of the 21st century. That is roughly 60% more people requiring food, fiber and other resources. The standard of living is improving for many of the developing nations around the world, and the demand for food, fiber and services will increase faster than the population growth. Agriculture is the foundation for sustaining that growth, and American agriculture can and should be leading the charge.

Now, let's focus a little more and look at some key points I will cover. 1) We should all work for the best interest of farmers–and ultimately for the consumer. 2) Industry is where the rubber meets the road. We are the force in contact with the farmer and at the same time have the ability to communicate with the public. 3) In industry we can promote, educate and support conservation tillage and sustainable agriculture. 4) We are international in scope and infrastructure and can influence attitudes and practices around the world. Now, let's consider each of these points in more detail.

FARMERS AND CONSUMER INTEREST

We in agriculture all work for the farmer and ultimately the consumer. If we don't work in the best interest of our customer, the farmer, we will not have a customer. This is true for industry, and it is true for university extension, university research and other public sector providers of information and services.

Too frequently, industry is portrayed as the "big bad monster" out to take advantage of the consumer. Profit is depicted as bad. Profit is what supports the research to bring new technologies and better crops on line. These new technologies and better crops enhance the farmer's position in the marketplace and also provide a more reliable food and fiber supply forthe world. Practices and policies that ensure a continuing productive agriculture are essential to meeting the demands of a growing and more prosperous world citizenry.

We have a responsibility to keep our food supply safe and our environment healthy, through wise and proper use of all crop inputs and management practices. The consumer–the public–ultimately determines how well we are doing in maintaining a safe food supply and how well we communicate that fact to the public. We have a major responsibility to educate the public about the real issues and the facts, as we know them, related to safe and effective food and fiber production.

We in industry must do an even better job than we are doing to counter the negative press leveled at agriculture in general and, more specifically, at farmers and industry. Much of the negative comment comes from individuals or groups with little knowledge of crop production. Their knowledge of fertilizer nutrients, chemical and other inputs is limited. We can work to change that through our public relations efforts. We must, however, be careful that we present truth and fact. We cannot hide the dangers where they exist. Honesty is essential if we are to impact the attitudes of those with negative opinions about agriculture.

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Presented at the 1997 Conservation Tillage Convention, Gainesville, Florida, but arrived too late for inclusion in the 1997 Proceedings.

INDUSTRY COMMUNICATES

Industry is where the rubber meets the road. We have more direct contact with the farmers than any other group. We deliver to them the products, services and information they want and need. We have the infrastructure to reach virtually every farmer in the country. We also have the ability to provide the equipment, chemicals, fertilizers, seeds, services and information they need to be successful. We have an excellent opportunity to promote and assist in the adaption of responsible stewardship through the use of proper conservation practices. Our people are trained and experienced to help growers understand the need for and the economic value of using best management practices in most situations.

Chemical and equipment companies develop and produce products designed for conservation tillage systems. New products are continually coming to the market, products designed to do a better job conserving residues while providing an ideal seedbed for proper seed-to-soil contact. Precision farming and global positioning are now providing more information about soil variability, weed infestations, variability in yields and other factors affecting crop production. Along with this information, these technologies provide increased management opportunities within individual fields and across farming operations. Seed companies are using new technologies in plant breeding to develop crops that reduce the reliance on insecticides and are providing herbicide alternatives that are less threatening to the environment and to our water supplies. Research expenditures on all these new products and technologies are tremendous.

Because of reductions in appropriations, many universities have had to reduce their support for extension and their emphasis on applied research. Farmers therefore are more frequently looking to industry for information and assistance in crop management.

INDUSTRY PROMOTES, EDUCATES AND SUPPORTS

Industry plays an important role in promoting soil and water conservation. Many companies promote conservation tillage and sustainable agriculture through the products they develop, produce and market. Improved products enable farmers to better manage their cropping systems, including the use of conservation tillage to protect soil and water. Other companies promote conservation in conjunction with products they sell, even though those products may not be directly involved in soil conservation or soil productivity. Seed companies are an example of this type of industry. Seed is not directly related to conservation tillage, unless one considers emergence and seedling vigor. However, we promote soil and water conservation as a part of crop management training and information we provide to dealers and to farmers.

Industry personnel conduct hundreds of meetings each year and visit thousands of farmers on their farm. The meetings may be crop management meetings for farmers or they may be information meetings for dealers. Industry technical representatives or agronomists are contacts serving as sources of information for agricultural publications and other media types. These contacts provide numerous opportunities for companies to promote responsible stewardship of land and water. Within Pioneer Hi-Bred, Inc., each year we present an “Agronomist of the Year” award to an outstanding agronomist in our company. One criterion for earning this award is evidence that the agronomist has worked to foster environmental and conservation education.

We can support individual farmers, farm groups, community groups, state agencies, universities, government agencies and other groups as they promote and/or practice soil and water conservation and responsible stewardship of our nation’s resources. One great example is the Conservation Tillage Information Center (CTIC), spawned by independent companies with a vision, including ICI, DOW, Tye, Pioneer and others, along with government agencies. These private companies and government agencies cooperated to establish a clearinghouse for conservation information in the early to mid-1980s. The CTIC is flourishing and continues to provide conservation tillage information and support to individuals and groups nationwide.

As recently as the spring of 1997, a cooperative arrangement was announced between USDA and six national agricultural companies. One of these companies was Pioneer Hi-Bred, Inc. The others include Cargill, ConAgra, Farmland Industries, Monsanto and Terra Industries. They are providing financial support to the USDA for promoting landowners’ installation of conservation buffers to protect waterways.

John Deere supported publication of a Conservation Tillage Handbook several years ago. I served as an editor for this project when I was on staff at Western Illinois University. ICI a few years ago cooperated with the CTIC in promoting conservation tillage with videos and TV commercials. Many other companies have supported similar projects through the years. These few I have named serve only as examples of the role industry has played and is playing in the support and promotion of conservation tillage.

INDUSTRY PLAYS AN INTERNATIONAL ROLE

Agriculture has become increasingly more global over the past 10 or so years. That trend is continuing. Most major agricultural companies are international in scope and infrastructure. Because of this international presence, they have the opportunity to influence attitudes, practices and policies around the world as they conduct business. It is an opportunity to promote wise resource use and conservation to maintain a productive agriculture around the world. In the mid-70s I spent 18 months in Brazil working with the Federal University of Santa Maria in Rio Grande do Sul. I was there to help them strengthen their soil conservation program. At that same time, ICI was working closely with local farmers in that part of Brazil, providing technical assistance in the field as those farmers began to adopt no-till practices in soybean (*Glycine max* L. Merr.) production.

Loren Kruse of *Successful Farming*, has said that “If the entire world ate as well as we do in the top eight exporting countries, we’d increase exports by four times! Those of us in agriculture want to see those countries develop and earn money....and spend it for our food products.” We can help ourselves if we help those countries develop and maintain their ability to produce food and fiber.

SUMMARY

Industry has a role in conservation tillage. We have been seriously taking responsibility for that role for many years and continue doing so today. You may ask why we, in industry, are interested in supporting conservation tillage and other such endeavors. There are two major reasons. 1) Profit or business. We want to stay in business and that requires a long look. It requires us to focus on what is best for our customers–farmers–in the long haul. We must help keep farmers profitable to maintain a market for our products and services. 2) A benevolent spirit. We want to be good community citizens. Industry or companies are made up of people. As people, we too are interested in creating a better world. We live in this world. Our children live in this world. Many of us have grandchildren who live in this world. We want the generations descending from us to have at least as good a world as we have in which to live and raise families.

EVALUATION OF CORN PLANTING DATES FOR NORTHERN MISSISSIPPI

J.R. Saunders and J.R. Johnson[1]

INTRODUCTION

Early planting of corn in Mississippi has the potential for higher yields because corn matures in a window of ideal temperature and rainfall. With the opportunity to forward contract corn above $2.50/bu, more acres are being planted in Mississippi. The window for corn planting becomes narrow considering the days available for field work. Pendleton and Grogan (1966) recommend planting corn in Mississippi from late March to early April. Since Mississippi is over 300 miles north to south, the dates for all parts of the state have to be adjusted accordingly. Soil temperature at corn planting time approximates 50 degrees (Genter and Jones, 1970). We find that we get not only higher yields, but less lodging, disease and insect damage when corn is planted early. Corn planting dates for the 1990's may have earlier planting dates due to new hybrids and herbicides. However, the rule of thumb for corn planting is late March to early April.

The primary reason for early planting is better yields. Other advantages can be enumerated and are as follows: 1) less lodging due to shorter plants and lower ears, 2) early plant growth before seasonal evapo-transpiration rates are high, 3) early pollination allows corn to pollinate before the hot, dry days of July and August and during the longest days of the year (around 21 June), 4) more available moisture in early summer than late summer, and 5) grain dries sooner allowing earlier harvest (Pendleton and Grogan 1966).

Weather data show an average of eight days in March in which field conditions are suitable for work in northern Mississippi. This narrows the window for corn planting between late March and early April. The objective of this study was to determine if corn planted during mid-February and early March would have yields comparative to those of corn planted during late March and early April.

METHODS AND MATERIALS

Five planting dates were established in 1995 to determine the optimum date to achieve maximum grain yield. Planting dates began 15 February and ended 15 April in two-week intervals, although dates varied slightly because of field conditions. A corn hybrid of Pioneer 3165[2] was chosen from past results in variety trials for Mississippi. The seeding rate for each date was 27,500 seed/acre in 38-in. rows. The site selected for this study was at the North Mississippi Branch Experiment Station in Holly Springs, Mississippi, on a Grenada silt loam soil with 0-2% slope. Crop residue in 1995 for the test site was less than 5%. Experimental design of the study is randomized complete block (RCB) with four replications. Each plot consisted of four rows on 38-in. spacing planted no-till (NT). A pre-plant burn-down herbicide of Gramoxone (paraquat) and nonionic surfactant was broadcast applied at 0.9375 lb ai /acre and 0.5% by volume, respectively. A granular blend fertilizer was surface applied according to soil test for 15-bu yield. Preemergence herbicides Aatrex (atrazine) and Dual (metolachlor) were broadcast applied after planting at 2.0 and 1.0 lb ai/acre, respectively. A post-emergence application of Accent (nicosulfuron) was applied at 0.67 oz/acre as needed for control of johnsongrass. Liquid nitrogen in the form of UAN was cut in at 150 lb with a ground rig when the corn plant was approximately 20 in. tall. All plots were harvested with a combine modified for plot harvest. The two center rows of the four-row plots were harvested, and grain yields were converted to bu/acre.

RESULTS AND DISCUSSION

It should be noted that these planting dates were established for northern Mississippi. Planting dates should be considered depending upon region and climatic conditions. All yields were based on small plots, not large-farm demonstrations.

Preliminary results of five planting dates (PD) of corn indicate that maximum grain yields were achieved for the first week of April when averaged over three years (Table 1). Average yield from 1995-1997 was 125 bu/acre. There was, however, an average decrease of 20% in yield or 25 bu/acre after the first week in April. Three-year yield averages for mid-February and early March were 56 and 28% lower than for the 1 April planting date. All planting date yields for 1997 were reduced significantly.

Data indicated that yields were lower after two years of continuous no-tilling regardless of planting date of corn; however, no visible signs were noted of insects or disease present from the practice of continuous no-till corn production on these plots. A significant yield reduction was noted between 1 April and 15 April planting dates in 1995

[1]Mississippi State University.

[2]The mention of a trademark or proprietary product does not imply endorsement by MSU or MAFES.

and 1996. The grand means for final stand population across five planting dates have been reduced by 4% in 1995, 21% in 1996 and 50% in 1997 (Table 2). High-residue plantings should be avoided unless residue is chopped finely and evenly distributed (Johnson, 1981).

Grain moisture readings taken the first week of August each year averaged 38.9%. Grain moisture readings were also taken the first week in September of each year. The average grain moisture for the first week of September on each planting date was (PD1) = 11.8%, (PD2) = 14.1%, (PD3) = 15.3%, (PD4) = 17.2%, (PD5) = 25.2%. This results in percent dry down per day to be for (PD1) = 0.9%, (PD2) = 0.8%(PD3) = 0.8%, (PD4) = 0.7%, and (PD5) = 0.5%. From the average, it appears that percent grain moisture is directly related to date of planting, regardless of yield (Table 3).

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Table 1. No-till corn grain yields by planting dates for North Mississippi Branch Experiment Station, Holly Springs, Mississippi, for 1995-1997.

Date of Planting	1995	1996	1997	3-yr. avg.
	---------------------------bu/acre-------------------------			
15 Feb.	107	51	8	55
1 Mar	139	91	44	91
15 Mar.	144	147	68	120
1 Apr.	147	154	73	125
15 Apr.	104	123	75	101
LSD (0.05)	39	29	5	
CV %	22	19	28	

Table 2. Final stand population per acre across five planting dates for North Mississippi Branch Experiment Station, Holly Springs, Mississippi, for 1995-1997.

Date of Planting	1995	1996	1997
	---------------------x1000----------------------		
15 Feb.	24.0	17.8	2.7
1 Mar.	24.2	19.7	10.8
15 Mar.	25.8	20.6	15.2
1 Apr.	26.5	24.4	18.9
15 Apr.	26.5	26.0	22.4
Mean	25.4	21.7	14.0

Table 3. Average percent grain moisture readings approximately 30 days prior to harvest and at harvest for percent dry down per day on five planting dates at North Mississippi Branch Exp. Stn., Holly Springs, Mississippi, 1995-1997.

	Grain Moisture		Dry Down/
Date of Planting	~Aug. 1	~ Sept. 1	day
	----------------------%----------------------		
15 Feb.	38.8	11.8	0.9
1 Mar.	38.1	14.1	0.8
15 Mar.	39.3	15.3	0.8
1 Apr.	38.2	17.2	0.7
15 Apr.	40.2	25.2	0.5

CONVENTIONAL VS. ULTRA-NARROW ROW (UNR) COTTON IN DIFFERENT TILLAGE SYSTEMS

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ABSTRACT

This research was conducted in 1996 and 1997 on a Dothan sandy loam (fine, loamy siliceous, thermic Plinthic Kandiudults) located at the North Florida Research and Education Center (NFREC), Quincy, Florida. The objective was to compare 36-in. row-spaced cotton planted with a Ro-till planter vs ultra-narrow row cotton (UNR) with 7-in. row width planted with the Great Plains no-till drill (both planted in minimum and conventional tillage). Four nitrogen treatments (0, 60, 120 and 180 lb N/acre) were applied in 1996 and three N rates (0, 60, 120 lb N/acre) in 1997. Higher cotton emergence was obtained on conventional row width in strip till than UNR. Increased N rates generally increased number of bolls/ plant for both row treatments with higher increase of boll number in conventional row width when compared to UNR. Significantly higher yields of cotton were obtained for UNR when compared to conventional rows with the highest lint cotton yield on UNR at 120 lb N/acre.

INTRODUCTION

Cotton production has increased rapidly in Florida, from 49,000 acres in 1991 to 98,000 acres in 1996 with the production of 73,000 bales (1 bale = 480 lb) in 1991 to 130,000 bales in 1996. According to Touchton and Reeves (1988), conservation tillage systems have a beneficial effect on cotton production in the sandy coastal plain soils of the southeastern states, but the formation of tillage pans due to soil compaction has also been recognized as a possible limitation in these soils. Torbert and Reeves (1991) showed that, in years of below-normal rainfall during the growing season, strip tillage (no-till plus in-row subsoiling) was found to maintain the highest seed cotton yield. Fertilizer-N application had no effect on cotton yields in an extremely dry growing season, suggesting that the beneficial effect of N fertilizer may be limited under such conditions.

Studies conducted near Stoneville, Mississippi, on the UNR cotton showed no effect of row spacing on seed cotton yields (Heitholt et al., 1993). The results suggest that some agronomic traits of cotton might be expected to be similar regardless of row spacing; therefore, management practices, such as recommendations for the rate and timing of defoliation chemicals, do not necessarily need modification in narrow row systems.

According to the study conducted by Torbert and Reeves (1994) increasing N application increased cotton biomass and decreased lint percentage. In a dry year, 1990, non-traffic decreased seed cotton yield from 1500 to 1360 kg/ha (1335 to 1210 lb/acre, respectively) while tillage had no significant effects on cotton yield components. Above-normal rainfall and the strip-till with non-traffic treatment gave the highest seed cotton yield of 2749 kg/ ha (2445 lb/acre) and the greatest fertilizer N uptake efficiency (35%). Results indicate that the detrimental effects of traffic on N uptake efficiency may be reduced with conservation tillage systems and that higher fertilizer N application rates may not be needed for conservation tillage practices such as strip-till in Coastal Plain soils.

The objective of this research was to compare minimum and conventional tillage for cotton planted in 36-in. and 7-in. row spacings with different N rates on cotton.

MATERIALS AND METHODS

These studies were conducted on a Dothan sandy loam (fine, loamy siliceous, thermic Plinthic Kandiudults) located on the NFREC, Quincy, Florida, in 1996 and 1997. The experimental design was a randomized complete block with four replications. Plot size was 40 by 12 ft for conventionally planted cotton and 40 by 20 ft for UNR cotton in 1996 and 20 by 6 ft for all plots in 1997.

Experiment Conducted in 1996

Paymaster 1244 Roundup Ready/Bt (RR/Bt) cotton was planted in UNR following wheat in no-till with the Great Plains no-till drill at 2 seeds/ft of row (7-in. row spacing) and with a Brown Row-till implement and KMC planters at 3 to 4 seeds/ft of row (36-in. row spacing) 12 July 1996. On 9 August cotton was side-dressed with 60 and 120 lb N/acre (treatments with the rate of 180 lb N/acre got only 120 lb N/acre) using a Gandy Fertilizer spreader on UNR cotton and an FP Fertilizer spreader on 36-in. rows. An additional rate of 60 lb N/acre was applied on the treatment with 180 lb N/acre 4 September. Cotton was broadcast sprayed with Roundup at 1 pt/acre + Induce at 1 pt/25 gal H_2O 20 August. On 16 September cotton was broadcast sprayed with Dipel ES at 1 pt/acre + Lannate at 1 pt/acre to control the fall armyworms on cotton. Cotton was defoliated with Prep at 2 pt/acre + Harvade at 0.5 pt/ acre + Roundup at 0.5 pt/acre + crop oil at 1 pt/acre 30

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October and with Prep 1.5 pt/acre + Harvade at 0.5 pt/acre + crop oil at 1 pt/acre 13 November.

Cotton stand and boll number were obtained by counting plants and bolls on two 10-ft-long rows in conventionally planted cotton and a 60 ft^2 area on UNR cotton. Plant population was calculated per acre. Yield was not taken due to the late planting and early frost.

Experiment Conducted in 1997

Before cotton was planted, wheat was mowed from the entire study. The conventional section of the experiment was disc-harrowed and s-tine harrowed. Fertilizer 5-10-15 at 500 lb/acre was broadcast applied on the entire study 6 June. The same day, Paymaster RR/Bt 1244 cotton was planted in the UNR section with a Great Plains no-till drill at 2 seeds/ft of 7-in.-wide rows and the 36-in.-wide row cotton was planted with a Ro-till implement and KMC planters at 3 to 4 seeds/ft of row. On 19 June 19 and 3 July, cotton was broadcast sprayed with Roundup Ultra at 1.5 and 1 pt/acre, respectively.

Karate at 4 oz/acre + Agridex at 1 qt/acre was applied 19 August and 3 September to control the insects. On 4 August, cotton was broadcast sprayed with Pix at 8 oz/acre + Agridex at 2 pt/acre. A second application of Pix at 12 oz/acre + Agridex at 2 pt/acre was made 27 August. Two N rates at 60 and 120 lb N/acre were applied on UNR cotton with a Gandy fertilizer spreader and on conventional rows with an FP fertilizer applicator 8 August.

Cotton was irrigated with 0.5 in. H_2O/acre 11 June, 28 August, 23 September and 8 October. The entire study was defoliated with Prep at 1.5 pt/acre + Dropp at 1/6 lb/acre + Harvade at 8 oz/acre + Dash at 1 pt/acre + Finish at 1.5 pt/acre 21 October. On 10 November cotton was picked from the UNR section of the experiment with a stripper harvester, and the next day the 36-in.-wide cotton rows were picked with an International 782 spindle picker. The lint cotton yield from the sections picked with a spindle picker and stripper harvester was calculated as 38% and 31% of the seed cotton yield, respectively.

Data were analyzed using SAS (1989) by analysis of variance, and means were separated using Fisher's Least Significant Difference Test at the 5% probability level.

RESULTS AND DISCUSSION

In 1996, cotton emergence (Tables 1 and 2) was significantly higher in the conventional row width in strip-till than in UNR in no-till (60.9 and 46.7, respectively). However, there was no significant difference among N rates. In 1997, emergence was not different for either row width or N rates. Plant population was higher on UNR cotton as compared to conventional row width in 1996 and 1997 (65000 and 30900, 95700 and 31200, respectively) because of the higher planting rate on the UNR than 36-in.-wide rows (Table 3 and 4).

Plant height was not significantly different for any analyzed treatment in 1996. In 1997, significantly taller plants occurred on the conventional rows as compared to UNR (3.76 and 2.53, respectively), and heights increased with higher N rates (3.00, 3.08 and 3.35 at 0, 60 and 120 lb N/acre) (Table 5).

Higher rates of N generally increased number of bolls for both row widths with higher boll number per plant in conventional row width at 0, 60 and 120 lb N/acre (1.8, 3.3 and 6.5 bolls/ plant in 1996 and 10.2, 13.9 and 14.2 bolls/plant in 1997, respectively) as compared to UNR (0.8, 1.1 and 1.6 boll/plant in 1996 and 3.9, 4.7 and 5.8 bolls/plant in 1997, respectively) (Table 6 and 7). However, the rate of 180 lb N/acre significantly decreased number of bolls when compared to 120 lb N/acre on conventional row spacing (from 6.5 to 4.4 boll/ plant) in 1996.

In 1997, lint yields were significantly higher on UNR than on conventionally planted cotton (1076 and 786 lb/acre, respectively) (Table 8) and were also higher at the application of 120 lb N/acre as compared to 0 and 60 lb N/acre (1041, 876 and 875 lb/acre, respectively) in 1997. There was no significant influence of tillage systems and previous crops on the yield.

CONCLUSIONS

Plant population was higher on UNR as compared to conventional row widths. Number of bolls per plant generally increased with higher N rates and was higher on conventional rows than on UNR. Higher yields of cotton were obtained at higher N rates and were higher on UNR as compared to conventional rows.

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Table 1. Emergence of cotton at NFREC, Quincy, Florida, in 1996.

Row width	Nitrogen rate (lb N/acre) 0	60	120	180	Avg.
in.			% emergence		
36	63.9	58.6	57.5	63.6	60.9
7	47.1	46.5	46.2	47.0	46.7
Avg.	55.5	52.5	51.9	55.3	53.8

$LSD_{(0.05)}$ for row width 6.69
$LSD_{(0.05)}$ for nitrogen rate NS
$LSD_{(0.05)}$ for row width x nitrogen rate NS

Table 2 Emergence of cotton at NFREC, Quincy, Florida, in 1997.

Row width	Nitrogen rate (lb N/acre) 0	60	120	Avg
in.		% emergence		
36	57.1	66.7	60.3	61.4
7	67.1	74.1	64.8	68.7
Avg.	62.1	70.4	62.6	65.0

$LSD_{(0.05)}$ for row width NS
$LSD_{(0.05)}$ for nitrogen rate NS
$LSD_{(0.05)}$ for row width x nitrogen rate NS

Table 3. Plant population of cotton at NFREC, Quincy, Florida, in 1996.

Row width	Nitrogen rate (lb N/acre) 0	60	120	180	Avg.
in.		thousands/acre			
36	32.5	29.8	29.2	32.3	30.9
7	65.7	64.8	64.4	65.5	65.1
Avg.	49.1	47.3	46.8	48.9	48.0

$LSD_{(0.05)}$ for row width 7.75
$LSD_{(0.05)}$ for nitrogen rate NS
$LSD_{(0.05)}$ for row width x nitrogen rate NS

Table 4. Plant population of cotton at NFREC, Quincy, Florida, in 1997.

Row width	Nitrogen rate (lb N/acre) 0	60	120	Avg
in.		thousands/acre		
36	29.0	33.9	30.7	31.2
7	93.6	103.3	90.3	95.7
Avg.	61.3	68.6	60.5	63.5

$LSD_{(0.05)}$ for row width 14.6
$LSD_{(0.05)}$ for nitrogen rate NS
$LSD_{(0.05)}$ for row width x nitrogen rate NS

Table 5. Plant height of cotton at NFREC, Quincy, Florida, in 1997 (No significant differences in 1996).

Row width	Nitrogen rate (lb N/acre) 0	60	120	Avg
in.		ft		
36	3.53	3.77	3.97	3.76
7	2.47	2.40	2.73	2.53
Avg.	3.00	3.08	3.35	3.14

$LSD_{(0.05)}$ for row width 0.197
$LSD_{(0.05)}$ for nitrogen rate 0.241
$LSD_{(0.05)}$ for row width x nitrogen rate NS

Table 6. Number bolls on cotton at NFREC, Quincy, Florida, in 1996.

Row width	Nitrogen rate (lb N/acre) 0	60	120	180	Avg
in.		bolls/plant			
36	1.8	3.3	6.5	4.4	4.0
7	0.8	1.1	1.6	1.3	1.2
Avg.	1.3	2.2	4.0	2.8	2.6

$LSD_{(0.05)}$ for row width 0.70
$LSD_{(0.05)}$ for nitrogen rate 0.99
$LSD_{(0.05)}$ for row width x nitrogen rate 1.40

Table 7. Number bolls on cotton at NFREC, Quincy, Florida, in 1997.

Row width	Nitrogen rate (lb N/acre) 0	60	120	Avg
in.		bolls/plant		
36	10.2	13.9	14.2	12.8
7	3.9	4.7	5.8	4.8
Avg.	7.0	9.3	10.0	

$LSD_{(0.05)}$ for row width 1.02
$LSD_{(0.05)}$ for nitrogen rate 1.25
$LSD_{(0.05)}$ for row width x nitrogen rate ns

Table 8. The lint yields (lb) of UNR vs. conventionally planted cotton at NFREC, Quincy, Florida, in 1997.

N rate	Row spacing - 7 in. No-till	Conv.	Avg.	Row spacing - 36 in. Strip-till	Conv.	Avg.	Avg
lb/acre			N rate			N rate	
0	827	1176	1001	826	677	751	876
60	983	1046	1014	772	698	735	875
120	1196	1227	1212	788	953	871	1041
Avg.	1002	1150	1076	795	776	786	931

$LSD_{(0.05)}$ for row spacing 97.7
$LSD_{(0.05)}$ for N 119.6
$LSD_{(0.05)}$ for row spacing x N ns
$LSD_{(0.05)}$ for row spacing x tillage x N 293.3
$LSD_{(0.05)}$ for tillage ns
$LSD_{(0.05)}$ for row spacing x tillage ns
$LSD_{(0.05)}$ for tillage x N ns

COMPARISON OF BT CORN TO NON BT USING STRIP TILLAGE AT FOUR PLANTING DATES

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ABSTRACT

This research was conducted in 1997 on a Dothan sandy loam (fine, loamy siliceous, thermic Plinthic Kandiudults) located at the North Florida Research and Education Center (NFREC), Quincy, Florida. The objectives of the study were to determine if Bt corn offers an advantage over temperate and tropical corn in late planting, to compare silage and grain yields of corn over planting dates and to monitor insect pressure of corn at each planting date. Tropical corn gave satisfactory grain and silage yield, but grain yield dropped significantly after 15 May. Temperate corn was devastated by insects in June and July planting as compared to Bt and tropical corn. Yields of Bt corn silage and grain were lower at later planting probably due to diseases rather than insects, but this hybrid showed potential for late planting as compared to temperate corn. Tropical corn had more insect damage than Bt corn did but less disease, which allowed the tropical to grow to maturity.

INTRODUCTION

The Southeast imports more than 50% of grain used by livestock from the Midwest. Farmers need corn varieties that could be planted until 15 June to take advantage of weather, to allow double cropping after wheat, winter grazing and winter vegetables and to have resistance to insects and diseases. Corn is planted in Florida from 15 February to 15 April, at which time it is discontinued due to fall armyworms, corn earworm and diseases (rust, leaf blight). Having a wide planting window would allow better use of silage and grain storage, better utilization of planting and harvest equipment, spreading of labor to slower periods, better utilization of land and irrigation by multi-cropping and longer use of winter forages. Tropical corn has some insect tolerance, generally good shuck coverage and good disease resistance. Hybrids that are full season (125 days) usually yield better and have better disease resistance and better shuck coverage as is found in tropical corn. Bt corn would be useful for insect control for late plantings.

Corn is recognized as the “queen” of silage crops because it is energy-rich for cattle and has high tonnage and high proportions of digestible nutrients and structural carbohydrates needed to maintain desired rumen function in high producing dairy animals (Johnson, 1991). It can be consistently harvested and stored with only minimal loss of nutrients and dry matter. Corn is an outstanding, dependable crop when grown under irrigation when planted early in the deep South and is very adaptable to harvesting by mechanical systems.

Wright et al. (1991) showed that temperate corn planted in early spring yielded more than tropical hybrids in both grain and silage. As planting dates were delayed, more reliable silage and grain yield were obtained from tropical hybrids because of better tolerance to insects and disease (Wright et al., 1991). Corn developed in the tropics is naturally more resistant to insect and disease (Martin, 1991) than corn developed in temperate regions.

Fall armyworm [*Spodoptera frugiperda* (J. E. Smith)] (Sprenkel, 1991) and corn earworm [*Helicoverpa zea*] (Anderson and Linker, 1991) are among the most common insects in corn and have the potential to adversely affect yields (especially late-planted crops). High non-economical rates of insecticides are needed to control fall armyworms because the larvae feed in the whorl or in the ear. Research has shown that it is possible to avoid fall armyworm damage by early planting (Teare et al., 1991).

The objectives of the study were 1) to determine if Bt corn offers an advantage over temperate and tropical corn in late planting and 2) to compare silage and grain yields of corn over planting dates and to monitor insect pressure of corn at each planting date.

MATERIALS AND METHODS

The experiment was conducted in 1997 on a Dothan sandy loam (fine, loamy siliceous, thermic Plinthic Kandiudults) at the North Florida Research and Education Center, Quincy, Florida. Three varieties of Pioneer corn were used to plant in the strip tillage: 3098 (tropical corn), 31B13 (Bt corn) and 3223 (temperate corn). Corn was planted 21 April, 15 May, 16 June and 7 July. Prior to planting, rows were ripped with a Ro-till implement, and the entire study was broadcast sprayed with Roundup Ultra at 1 qt/acre + Induce at 2 qt/100 gal of water. Fertilizer was broadcast applied at 500 lb/acre of 5-10-15 before planting. All three varieties were planted with a cone planter at 24,000 plants/acre with the application of Thimet 15 G. Corn was broadcast sprayed with atrazine at 1 qt/acre when it was 5 in. tall and side-dressed with 450 lb/acre of 34-0-

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0 when corn was 12 in. tall. Corn was harvested for silage with a Hesston silage chopper, and the yields were adjusted to 35% DM. Corn for grain was hand harvested, weighed and adjusted to 15.5% moisture.

Data were analyzed using by analysis of a variance procedure (SAS, 1989), and means were separated using Fisher's Least Significant Difference Test at the 5% probability level.

RESULTS

Total fall armyworm larvae in the whorl was lower for Pioneer 31B13 (Bt corn) on all dates measured than for Pioneer 3223 (temperate corn) and Pioneer 3098 (tropical corn) (Table 1). The highest average number of fall armyworms was recorded for 16 June and 7 July, and Pioneer 3223 had the highest population of the hybrids. The number of fall armyworms did not differ among corn hybrids planted 15 May. Whorl injury was highest for Pioneer 3223 as compared to Pioneer 3098 and Pioneer 31B13 for all planting dates, with the highest injury on corn planted 16 June and 7 July (Table 3).

Total population of larvae in corn ears is shown in Table 2. There was not a significant difference for total larvae in the ear for hybrids planted 21 April. The larvae population was lower for Bt corn than for tropical corn planted 15 May. For the 16 June planting date, the Bt corn had more larvae in the ears than the other two hybrids. For the 7 July planting date, the Bt corn had fewer larvae than the temperate hybrid.

Silage yields of corn are shown in Table 4. The yields of Pioneer 3098 were not significantly different at the 5% probability level for all four planting dates. Pioneer 31B13 silage yields were highest planted 15 May as compared to corn planted before or after this date. The yields dropped significantly for Pioneer 3223 if planted after 15 May. There was not a significant difference for the silage yields for the first planting date (21 April). The yields were higher for tropical corn and Bt corn when compared to temperate corn planted 15 May. For corn planted 16 June and 7 July, the yields were higher for Pioneer 3098 than for Pioneer 31B13 or Pioneer 3223.

Grain yields of corn are shown in Table 5. The yields of Pioneer 3098 were significantly higher planted 21 April and 15 May as compared to the 16 June and 7 July planting. Pioneer 31B13 planted 21 April yielded more grain than 15 May, 16 June and 7 July planting dates. Yields of Pioneer 3223 corn were higher when planted 21 April than when planted 15 May, 16 June and 7 July. There was not a significant difference among hybrids for grain yield when planted 21 April. Higher yields were obtained for tropical corn and Bt corn than for temperate corn when planted 15 May. Grain yields were significantly lower when planted 16 June. The highest yielding hybrid for this planting date was Pioneer 3098, which was greater than Pioneer 31B13 which was greater than Pioneer 3223. If the last planting is compared, higher yields occurred from tropical corn than Bt corn or temperate corn.

SUMMARY

Tropical corn gave satisfactory silage yield until early July, while grain yield dropped significantly after mid-May plantings. Temperate corn was devastated by insects in June and July planting as compared to Bt and tropical corn. Yield of Bt corn silage and grain was lower at later planting dates, largely due to diseases rather than insects, but this hybrid showed potential for late planting as compared to temperate corn. Bt hybrids had less insect damage than tropical hybrids and as later maturity hybrids are developed with good disease tolerance, satisfactory late plantings may be made.

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Table 1. Total larvae of fall armyworm in the whorl at NFREC, Quincy, FL in 1997.

Planting Date	Corn hybrid Pioneer 3098 (tropical)	Pioneer 31B13 (Bt)	Pioneer 3223 (temperate)	Avg.	$LSD_{(0.05)}$
	----------------number larvae per plant----------------				
April 21	0.25	0.03	0.23	**0.17**	0.158
May 15	0.15	0.06	0.21	**0.14**	NS *
June 16	2.16	1.73	4.59	**2.83**	0.812
July 7	1.03	0.90	6.31	**2.75**	0.955
Avg.	**0.90**	**0.68**	**2.83**	***0.95***	
$LSD_{(0.05)}$	0.386	0.686	0.781		

* NS - not significantly different at 5% probability level

Table 2. Total larvae in the ear at NFREC, Quincy, FL in 1997.

Planting Date	Corn hybrid Pioneer 3098 (tropical)	Pioneer 31B13 (Bt)	Pioneer 3223 (temperate)	Avg.	$LSD_{(0.05)}$
	----------------number larvae per plant----------------				
April 21	1.26	2.06	1.29	**1.54**	NS *
May 15	0.29	0.14	0.09	**0.17**	0.108
June 16	1.30	2.69	1.39	**1.79**	0.670
July 7	0.78	1.88	3.28	**1.98**	0.390
Avg.	**0.91**	**1.69**	**1.51**	***1.37***	
$LSD_{(0.05)}$	0.315	0.777	0.433		

* NS - not significantly different at 5% probability level

Table 3. Percent whorl injury on corn at NFREC, Quincy, FL in 1997.

Planting Date	Corn hybrid Pioneer 3098 (tropical)	Pioneer 31B13 (Bt)	Pioneer 3223 (temperate)	Avg.	$LSD_{(0.05)}$
	------------------------------%------------------------------				
April 21	15.0	0.30	24.4	**13.2**	15.70
May 15	33.1	6.12	51.2	**29.5**	23.53
June 16	68.0	12.7	86.4	**55.7**	8.48
July 7	87.0	58.9	96.2	**80.7**	13.50
Avg.	**50.3**	**19.5**	**64.5**	***44.8***	
$LSD_{(0.05)}$	16.30	6.58	16.29		

Table 4. Silage yields of three corn hybrids over four planting dates at NFREC, Quincy, FL in 1997.

Planting Date	Corn hybrid Pioneer 3098 (tropical)	Pioneer 31B13 (Bt)	Pioneer 3223 (temperate)	Avg.	$LSD_{(0.05)}$
	---------------------------T/acre---------------------------				
April 21	17.2	16.2	15.9	**16.4**	NS *
May 15	22.0	18.9	15.2	**18.7**	4.64
June 16	19.8	13.2	6.0	**13.0**	2.89
July 7	16.7	9.2	4.4	**10.1**	1.20
Avg.	**18.9**	**14.4**	**10.4**	***14.6***	
$LSD_{(0.05)}$	NS	1.57	2.13		

$LSD_{(0.05)}$ for planting date 1.53 $LSD_{(0.05)}$ for corn hybrid 1.32

$LSD_{(0.05)}$ for planting date x corn hybrid 2.65

* NS - not significantly different at 5% probability level

Table 5. Grain yields of three corn hybrids over four planting dates at NFREC, Quincy, FL in 1997.

Planting Date	Corn hybrid Pioneer 3098 (tropical)	Pioneer 31B13 (Bt)	Pioneer 3223 (temperate)	Avg.	$LSD_{(0.05)}$
	----------bu/acre----------				
April 21	133.3	129.9	122.2	**128.5**	NS *
May 15	127.3	107.8	82.5	**105.9**	4.64
June 16	83.5	46.1	7.9	**45.9**	2.89
July 7	87.5	42.7	3.6	**44.6**	1.20
Avg.	**107.9**	**81.6**	**54.1**	***81.2***	
$LSD_{(0.05)}$	14.9	16.8	15.0		

$LSD_{(0.05)}$ for planting date 8.00 $LSD_{(0.05)}$ for corn hybrid 6.93

$LSD_{(0.05)}$ for planting date x corn hybrid 13.85

* NS - not significantly different at 5% probability level