SOIL PROFILE MODIFICATION AND COTTON PRODUCTION[1]

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Abstract

Hardpan soils of the southeastern Coastal Plains were mixed to depths up to 0.61 m in an attempt to alleviate strength problems associated with a subsurface pan. It was hypothesized that mixing the dense, coarse-textured E Horizon with the less dense A_p and the relatively clayey B horizon would increase the water-holding capacity of the E and decrease its strength. Mixed soil did have a higher amount of water held than the unmixed E, increasing it from 5 to 7% at -200 kPa matric potential. This would reduce its strength by approximately 0.1 MPa allowing easier root penetration whether the increased water is available for uptake or not. Although seed cotton in the deeply-mixed treatments outyielded the moldboard-plowed treatments by 233 kg/ha in one year, they were outyielded by 132 kg/ha in another year. The decrease in strength and the increases of retention as a result of the mixing were small and infiltration was unchanged. Furthermore, mixing of field samples was less homogenous than lab samples. It is doubtful that the level of improvement of cotton would warrant the effort involved in the mixing operation.

Treatments at two sites were split into fertility subplots. The only significant fertility difference was between rates of N sidedressed when plants were about 0.40 m tall. The 20 kg/ha rate outyielded the 67 kg/ha rate by up to 300 kg/ha presumably because the higher rate encouraged vegetative growth and retarded boll formation which in turn limited lint and seed production. Interactions between tillage or mixing and fertility were non-significant. Plants grew better in the deeper disturbed soils in dryer years. Other crops may respond more favorably to the mixing.

Introduction

Ultisols of the Atlantic and Gulf Coastal Plains are derived from parent materials high in sand and silicate clays (Buol, 1973). These soils have low pH, base exchange, organic matter, and water retention and high bulk density. They cover large areas in the thermic-humid coastal Southeast where winter precipitation usually exceeds transpiration. Summer precipitation is usually not enough to provide for the evapotranspirational demand of most field crops. Paleudults comprise much of the cropped area and possess physical and chemical properties that influence production management procedures (Campbell et al., 1974).

The A horizons of these paleudults are generally grey in color and 0.10 to 0.20 m thick. They commonly rest on a grey E horizons which, if present, can be as thick as 0.38 m. The E horizon can have a natural bulk density as high as 1.70 Mg/m^3 and strengths that completely prevent root penetration at matric potentials as high as -20 kPa (Campbell et al., 1974). These horizons lie within the reach of most primary tillage implements but are easily recompacted by ordinary tire traffic. A red to yellow-brown argillic B_t horizon commonly lies below the A_p and E horizons.

Mixing studies have been conducted by Unger (1970), Pearson et al. (1973), Robertson et al. (1976), and Bradford and Blanchar (1977). One was conducted in the Southeastern Coastal Plain by Fitts (1962). The benefits reported include increased infiltration and decreased bulk density and strength on heavier-textured soils (Unger, 1970; Bradford and Blanchar, 1977) and better root proliferation in lighter-textured soils (Robertson et al., 1976). Fitts (1962) mixed Coastal Plain soils with large disks to as deep as 0.75 m and reported moderate increases in cotton yields.

In this study, the E horizon was completely or partially eliminated by incorporating it (or part of it) with the A and part of the B horizons. It was hypothesized that mixing would increase the water holding capacity and decrease the strength of the E horizon. This would increase the rooting volume and accessibility of soil water and nutrients. It would also permit the roots to explore the heavier-textured B horizon which is higher in clay content, water holding capacity, and CEC than the A. This can aid in reducing plant-water stress which is a result of frequent, short-term summer droughts and sandy surface layers of the Southeastern Ultisols.

Materials and Methods

Soil Modification

Soil modification was performed on a Norfolk loamy sand which also has a loamy sand texture in the E horizon and a sandy clay texture in the B horizon. Effect of modification on cotton, *Gossypium hirsutum*, production was evaluated over a 5-year year period at two sites near Florence, SC. Experimental variety 'Pee Dee 0259' was grown at Site 1 in the first year of the study. Coker 201 was grown at both sites thereafter. At Site 1, upper and lower boundaries of the E horizons were approximately 0.20 and 0.37 m. At Site 2, these boundaries were approximately 0.17 and 0.30 m, respectively. The E and varying portions of the B horizons were mixed with the A horizon using a trenching machine at depths of 0.25, 0.30, 0.37, and 0.46 m at Site 1 in the first year of the study and 0.30, 0.46, and 0.61 m at Site 2 in the following year. Moldboard plowing to a depth of 0.18 m was included as a conventional treatment at both sites. Cotton was grown at Site 1 for the first 2 years of the experiment and at Site 2 for the next 3 years.

Mixed and conventional tillage plots were approximately 6 by 61 m at Site 1 and 6 by 75 m at Site 2. They were replicated 4 times and split into fertility subplots (described later). Since a tillage pan was identified at Site 2, main treatments were split into tillage subplots in the last two years of the experiment. These consisted of (1) subsoiling to 0.60 m, (2) chiseling to 0.30 m, and (3) moldboard plowing.

Fertilization

Fertilizer was broadcast on the surface at both sites before the mixing operation. At Site 1, five rates of fertilization shown in Table 1 were broadcast as subplots for each main treatment. Recommended amounts of B and Mg were broadcast at the same time. In the following year, fertilization was uniform over the plots at a rate of 112, 59, and 150 kg/ha of N, P, and K, respectively.

In the second year of Site 1, Site 2 was developed. It was planted to cotton in the following year. For the first year of cotton planting at Site 2, fertilizer was uniformly applied at a rate of 50, 45, and 84 kg/ha for N, P, and K, respectively. Twenty-four days after planting, 56 kg/ha of N and 47 kg/ha of K were applied as a sidedressing. In the next year at Site 2, fertilizer was uniformly applied at rates of 31, 41, and 78 kg/ha of N, P, and K, respectively. When plants were approximately 0.27 m tall, 67 kg/ha of N was applied as a sidedressing. In the last year at Site 2, subplots were split using two rates of N fertilization. Initially, all plots received 25, 22, and 40 kg/ha of N, P, and K, respectively. Sidedressing was then split into 20 and 67 kg/ha of N applied when plants were approximately 0.40 m tall.

Soil Water Retention and Water Balance

Soil cores were taken from the A_p, E, and B_t horizons and from equal depths of the plots that had been mixed to 0.61 m. These cores were moistened on a wet sand bed with a water table within 13 mm of the surface and equilibrated on ceramic pressure plates at 10, 30, 80, and 200 kPa to obtain a water retention curve.

The number of days that the crop was experiencing stress was calculated using the soil water balance method. Actual evapotranspiration was assumed to be 85% of open pan evaporation. It assumed that all rainfall infiltrated into the soil and was used by the

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crop. Crop canopy factors for cotton of Doss et al. (1965) were used. Whenever the soil water was depleted for a day without replenishment, the crop was assigned one drought day.

Infiltration

A sprinkler infiltrometer, patterned after one used by Bertrand and Parr (1966), was used to measure infiltration for the different management regimes. The infiltrometer consisted of a wind shelter, nozzle, and spray collector pan mounted on a lightweight aluminum frame. Ground level components consisted of a plot frame, 1 m^2 x 2 m high, calibration pan, and runoff sump. Components mounted on a two-wheel trailer included a 1,000 l water supply, a sump pump, a nozzle pump operated at 41 kPa, a 0.1 m^2 runoff receiver tank, and a water stage recorder. The nozzle, used to simulate rainfall, was modified from Spraying System Model 7LA[3] to give an application rate of 55 mm/h. This was accomplished by machining a 1.2 x 5 mm slot in the core assembly and positioning a piece of 3.2 mm ID x 4 mm long tubing in the center. The tubing was adjustable and held in place by a set screw to improve water distribution in the center of the spray pattern. The collection pan was placed outside the 1.8 m^2 plot boundary. Runoff was continuously pumped and monitored on a strip chart water stage recorder.

Soil Strength

Norfolk loamy sand was used for both field and artificial-mixing studies. Textures for original horizons and mixes are shown in Table 2. The artificial mix was 21% A, 22% E, and 57% B. The effect of soil water potential and bulk density on strength was investigated.

The mix was combined with a twin shell dry blender. Lab samples were compressed to bulk densities ranging from 1.4 to 1.9 Mg/m^3 in 76 mm diameter cylinders that were 25 mm deep from which about half was trimmed off the top and bottom.

Field cores were taken with a locally-built sampler. A 25 mm deep, cylindrical core retainer, 76 mm in diameter, was fitted below a driving head and above a beveled driving tip. This was housed in a cylindrical guide attached to a larger rectangular plate which was stabilized by 50 mm pins welded on the corners that were driven into the soil for stability during sampling.

Samples were moistened and equilibrated in the same manner as the soil water retention samples. Probe resistance was measured with a 5 mm flat stainless steel tip attached to a strain gage load cell driven at a constant rate of 0.28 mm/sec described in Spivey et al. (1986).

Results and Discussion

Tillage

The deep tillage subplots that were introduced for the last two years of cotton at Site 2 because of the pan identified there were not significantly different in yield from plots that were not deep tilled for the first year of these subplots. However, in the last year of the study, the second year for the deep tilled subplots, there was a significant (at the 5% level) increase in yield for both the chiseled and subsoiled plots over moldboard plowing. Lint cotton yields were 741, 645, and 586 kg/ha for the subsoiled, chiseled, and plowed subplots, respectively.

Fertilization

At Site 1, there was no significant difference in yield for the fertilizer application rates at the time of mixing, see Table 1. Interactions between different depths of tillage or mixing and fertility rates also showed no significant difference in yields. There was a significant difference in yield, however, between the two rates of N split on the sidedressing at Site 2. The lower rate outyielded the higher by 300 kg/ha for the mixed soil, as shown in Table 3. These differences were most consistent in the subsoiled subplots. Annual subsoiling maintains a zone of loose soil which can increase the overall water availability and nitrogen uptake by enhancing root growth. It is hypothesized that this could encourage vegetative growth which retards boll formation. Increased water availability from subsoiling together with added nitrogen could have a synergistically detrimental influence on cotton yield.

Soil Water Retention

For a given matric potential, the mixed soil material of Table 2 had a higher water content than the A or E horizons but considerably less than the B horizon (Figure 1). Water retained between potentials of -10 and -200 kPa were 7.6%, 5.3%, 4.4%, and 5.3% for the A, E, and B horizons and mix, respectively. Between -30 and -200 kPa, the four horizons released 3.5%, 2.4%, 2.5%, and 2.6%. Although the mixing increased the amount of water held at tensions between -30 and -200 kPa (Figure 1), it did not increase the amount of water released between these tensions. The low amounts of available water point to the need to increase the soil volume from which roots can extract water during periods of low rainfall.

Infiltration

Cumulative infiltration and infiltration rates are shown in Figure 2. The data represent averages over five replicates at Site 1 for the moldboard plowed and deepest mixed profile (.46 m). Initial infiltration rates were lower for the mixed treatment. After about 1 hour, rates were about equal at about 15 mm/h. Early differences in infiltration rate accounted for a slightly lower total intake for the deep mixed treatment. The test did not, however, show that mixing soils appreciably altered the infiltration.

Soil Strength

Probe resistance has been used as an estimate of soil strength and resistance to root growth. Although actual limits of growth are disputed (Taylor et al., 1966, Camp and Lund, 1968, Campbell et al., 1974, Blanchar et al., 1978, Gerard et al., 1982, Ide et al., 1987), the bulk of existing literature shows that for the Coastal Plain soils, cotton root growth is restricted beyond 2.0 MPa as measured by the 5 mm, flat-tipped penetrometer. Figure 3 shows the penetrometer resistance as a function of water potential for the three soil layers and the mix.

Figure 3 also shows average bulk densities of the field condition. The high density of the E horizon contributes to its high strength characteristics; the layer is easily compacted (Spivey et al., 1986). The A horizon has moderate strength characteristics. Mixing about one-half B horizon material with about one-half A and E reduced the strength of the soil substantially below that of the E material alone. However, the difference was not as noticeable in the deep mixed field samples of Figure 3. Although the lab mix was chosen to simulate field mixing sites, there was a notable difference between the two. Both had approximately 50% B horizon; however, lab samples were well mixed, while field sites had clumps or clods varying from small granules to fist-size.

Computed soil strength, as it varied across the growing season, is shown in Figure 4. This data was generated from a known relationship of water content and bulk density with soil strength for Norfolk loamy sand developed by regression similar to Spivey et al. (1986). Strength was calculated from measurements of water content and bulk density assuming that the bulk density did not change appreciably throughout the growing season. In the period from mid-May to late July, computed soil strength remained between 1 and 2 MPa, moderate resistance to root elongation. However, after that, computed strength exceeded 2 MPa until mid-September, except for a brief period in August. After late July, computed strengths indicate that root growth would be severely restricted, and roots would be unable to explore the soil for additional water and nutrients. This illustrates the dependence of soil strength on moisture and the unfortunate coincidence that as the root desiccates the soil, it increases strength making the soil less favorable for further root growth.

Yield

Yield trends associated with the soil mixing are not consistent over the 5-year study as shown in Table 4. For two years, the deepest mixed treatment was significantly higher in yield, for two years it was significantly lower, and for one year it did not differ. This is believed to be a result of the combined effects of cotton maturity and plant-water relationships. Seed cotton yields as a function of the number of drought days are shown in Figure 5. Mixed soils should have been beneficial because of the increased water-holding capacity of the surface horizons, as well as any residual effect of the loosening action of the mixing permitting greater root proliferation. For cotton, however, this can be a disadvantage since stress encourages the boll ripening. This is generally born out by the data in Figure 5. In years with fewer drought days, years of 'favorable' growth conditions, the turnplowed treatments outyielded the deep mixed treatments. In this case, deep mixed treatments tended to be more vegetative at the expense of fruiting. In years one and two at Site 1, this proved to be the case, though the yield difference was significantly different for only year two. This was partially verified in years 3 and 4 where the deep mixed treatment outyielded the plowed treatment in year 3 and vice versa in year 4. The plants for the deep mixed treatments were significantly taller than the plowed treatment both years, 0.22 and 0.24 m, respectively.

For years three and five, growing conditions were not 'favorable'; there were 70 to 75 drought days. In these years the increased moisture content would be needed for proper plant maintenance. Increased availability of water or increased rootability would help alleviate the detrimental effects of the drought.

In years of adequate water supply from rain for the turnplowed treatments, the increase in available water from the mixing led to greater vegetative growth at the expense of seed cotton yield. In years where more water is needed yield is increased by the availability of the extra water in the less dense soil.

Since the slope of the deep mixed treatment is steeper than that for the turnplowed treatment in Figure 5, it is apparently more sensitive to an increase or decrease of drought days. In neither case has the condition for maximum yield been found. After the optimum growth conditions are found, the conditions may be more conventional. For crops that do not ~~exhibit~~ yield reduction in this manner, mixing may be an more of an advantage.

Conclusions

Strength of the E horizon in the field was not reduced as much as expected partially because of the incomplete nature of the mixing in the field. The amount of water held by the E horizon did increase and would reduce its strength allowing roots to more easily grow through it even if the additional water were not available for uptake.

Mixing did not improve the infiltration of water into the soil. Infiltration rates of the deep mixed treatments were reduced when compared to the moldboard-plowed treatments, although this difference was not significant.

Mixing to any of the depths did not consistently improve cotton growth or yield. It does not appear that the improvement to strength or water retention would have been great enough for cotton to warrant the expense involved.

Acknowledgments

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Table 1. Fertilization splits for Site 1

	Rate (kg/ha)		
	N	P	K
A	123	20	112
B	160	184	146
C	202	230	216
D	249	282	267
E	274	431	249

Table 2. Soil textures for the field and artificially-mixed samples

	Percent		
Horizon	Sand	Silt	Clay
A	75.2	15.8	3.2
E	68.6	22.3	4.7
B	52.1	18.1	28.5
mix	59.5	19.2	17.8

Table 3. Seed cotton yield of soil mixes with tillage sub-plots and N sub-sub-plots

	Cotton yields (kg/ha)					
	Tillage splits					
Original	Plowed		Chiseled		Subsoiled	
Tillage N(kg)=	67	20	67	20	67	20
Plowed	1121	1438	-*	-	1975	1977
0.30 Mix	1402	1539	1611	1937	1612	1994
0.46 Mix	1772	1657	1748	1528	1831	2167
0.61 Mix	1971	1953	1715	1772	2001	2250

* Not a treatment.

Table 4. Cotton lint yield for moldboard plowed and deep-mixed soil

Tillage		Lint Cotton (kg/ha)				
		Site 1		Site 2		
		Year				
Type	Depth(m)	1	2	3	4	5
Plowed	0.18	410a*	342a	557b	360a	638b
Mixed	0.25	479a	305ab	-#	-	-
Mixed	0.30	434a	250bc	681a	293ab	621b
Mixed	0.36	391a	224c	-	-	-
Mixed	0.46	442a	252bc	787a	272b	652b
Mixed	0.61	-	-	790a	228b	720a

* Grouped by Duncan's test. Means with the same letters are not significantly different at the 5% level.
# Not all depths were used at both sites.

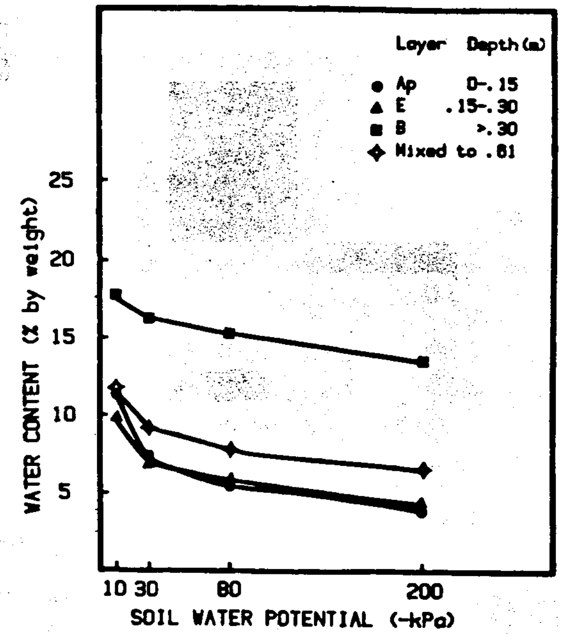

Figure 1. Characteristic curves for three soil layers and lab mix.

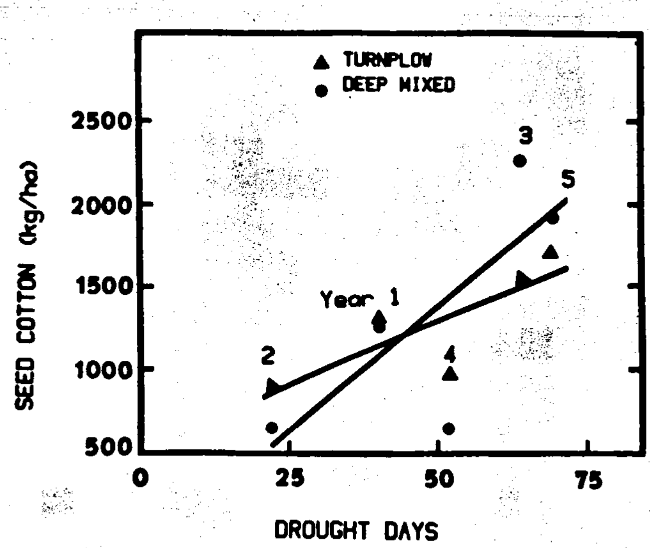

Figure 5. Seed cotton yield as a function of the number of drought days throughout the growing season for the first two years at site one and the last three years at site 2.

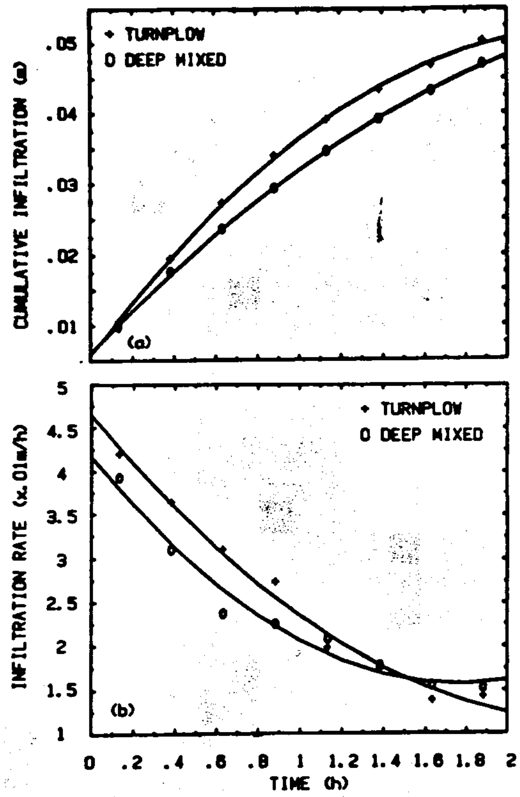

Figure 2. Cumulative infiltration (a) and infiltration rate (b) for the control and the deeply mixed treatments.

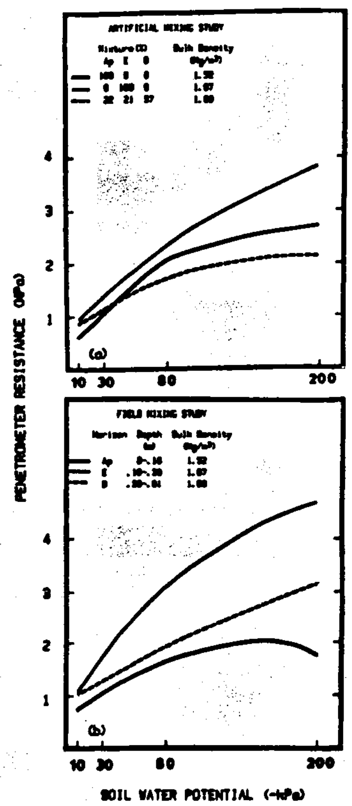

Figure 3. Soil strength as a function of soil water potential for the disturbed laboratory samples (a) and samples taken from the field (b).

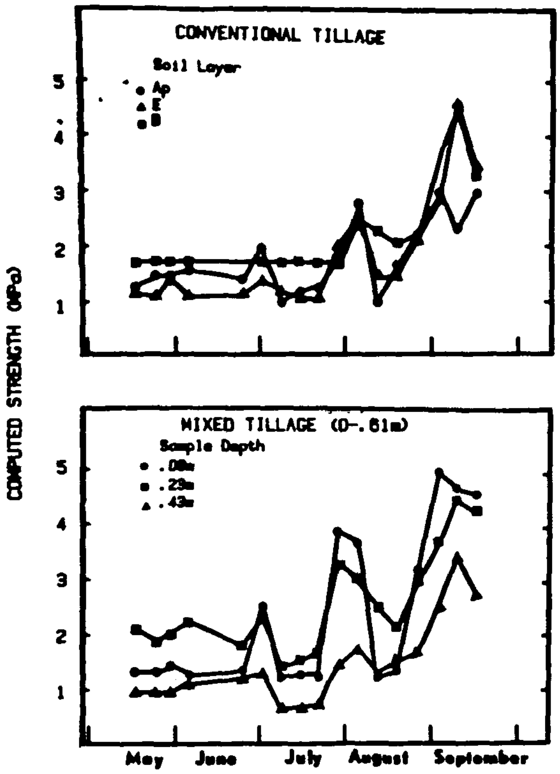

Figure 4. Soil strength computed from regression equation as a function of time for the conventional and deeply mixed tillage treatments.

EFFECT OF NITROGEN FERTILIZER RATES AND DEFOLIATION TIMING ON COTTON YIELD AND QUALITY-A GOSSYM-COMAX COMPARISON

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Key Words: Gossym-Comax, Seed cotton, Micronaire, Lint percent, Nitrogen, Defoliation, Cut-out

Abstract

The effects of two nitrogen (N) fertilizer rates and four defoliation applications on cotton yield and quality were determined at two test sites located at the Tennessee Valley Substation in northern Alabama. Results were compared to those predicted by the Gossym-Comax cotton computer model. The test sites were planted two weeks apart and the normal N fertilizer rate for the area (70lb/A) was compared to the N fertilizer rate recommended by Gossym-Comax. In this study, Gossym-Comax cotton plots received N fertilizer at the rate of 70lb/A preplant, 30lb/A sidedress and 20lb/A foliar. All the cotton was non-irrigated. To pin-point the optimum defoliation date, cotton was defoliated at three to four day intervals beginning one week before the defoliation date predicted by Gossym-Comax. Cotton yields decreased slightly, but not significantly, by the addition N fertilizer recommended by Gossym-Comax. The different defoliation applications also did not significantly affect cotton yields. Cotton length and strength measurements were not affected by defoliation or N fertilizer applications. However, lint percentage and micronaire readings were reduced by the additional N applications above 70lb/A. In these tests, Gossym-Comax over-estimated the N fertilizer requirements of the non-irrigated cotton. Also, Gossym-Comax was one to over two weeks late in predicting defoliation which was caused by Gossym-Comax not terminating cotton growth when the severe drought conditions occurred in late July and August.

Introduction

Evaluation of the Gossym-Comax cotton computer model has been done primarily on irrigated cotton. Since the majority of cotton in Alabama is nonirrigated, experiments are needed under Alabama field conditions to evaluate Gossym-Comax's usefulness to Alabama cotton farmers. The benefits farmers would receive from using Gossym-Comax would appear to be in more accurately predicting N fertilizer requirements and defoliation date. Two field experiments were established with nonirrigated cotton in northern Alabama in 1987. These test were established with the following objectives: (a) Compare the current recommended N fertilizer rate for the area with the N rate recommended by Gossym-Comax, (b) Determine the effects of defoliation timing on cotton yield and quality. (c) Determine the accuracy of Gossym-Comax in predicting a cotton's crop defoliation date.

Materials and Methods

Two test areas were established on a Decatur silt loam (Rhodic Paleudult) on the Tennessee Valley Substation in north Alabama. The cotton variety(DPL 50) was planted in both sites and the growth regulator, PIX, was applied at a rate of one pint/ A at early bloom.

The normal N fertilizer rate for the area (70lb/A) was applied preplant to both test areas. Half the test areas received only this preplant N fertilizer rate, while the other half received additional N as required by the Gossym-Comax model (See Table 1). The sidedress and foliar N treatments were applied 7-10 days prior to the N stress periods predicted by Gossym-Comax.

Four defoliation applications were applied varing from when the cotton was from 29 to 71 percent open (Table 2). For a once over harvest, defoliation materials, Prep and Dropp were combined and applied at a rate of 1.0 lb/A and 0.05 lb/A a.i. respectively in 14 gallons of water/A.

The tests were arranged in a randomized split plot design with N treatments as main plots and defoliation dates as subplots. Plots were eight rows by 30 feet long and replicated four times. The center four rows were harvested for yield using a two-row spindle picker. Cotton samples were taken for lint percent, micronaire, fiber length and fiber strength measurements.

Results and Discussion

Near ideal weather conditions up to early July resulted in an excellent early cotton fruit set. However, drought conditions in late July and August caused most of the later cotton fruit to shed which resulted in an early harvested crop. Up to the drought period, Gossym-Comax was found to be accurately predicting the growth and development of the cotton plant. When the cotton plants under-went severe drought stress, however, the model did not "cut-out" as the cotton plants did in the field. Instead the model still added squares and developed the cotton fruit. This caused problems in Gossym-Comax's defoliation date prediction, which will be discussed later.

At the 70lb/A rate of N, Gossym-Comax under-estimated cotton yields (Table 3). Using 120lb/A of N fertilizer, Gossym-Comax was within 5 and 11 percent of the actual cotton yields on the early and late planted cotton, respectively (Table 3).

Cotton yields in both plantings were reduced slightly, but not significantly, by the additional N fertilizer recommended by Gossym-Comax (Table 4). Why this decrease occurred is unclear, but it may have been due, in part, to greater insect attraction to the greener high-N cotton. Cotton defoliation applications also did not significantly affect cotton yields (Table 4). This was particually surprising since the first defoliation on the late planted cotton occurred when the cotton was only 29 percent open.

As mentioned earlier, the Gossym-Comax model did not terminate cotton growth when the cotton plants in the field went into severe drought stress. Because of this, Gossym-Comax was about on week late in its defoliation prediction for the early planted cotton and over two weeks late on the late planted cotton (Table 4). With the late planted cotton, the last defoliation occurred when the cotton was 71 percent open. Gossym-Comax was not predicting defoliation until one week later.

Lower lint percent and micronaire measurements were found in the cotton grown with 120 lbN/A (Table 5). This would indicate that the higher N fertilizer rates resulted in some delay in maturity. Lint percent and