VESICULAR ARBUSCULAR MYCORRHIZAE (VAM) IN NO-TILLAGE COTTON

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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.

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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.

	Tillage Method	
Area	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.