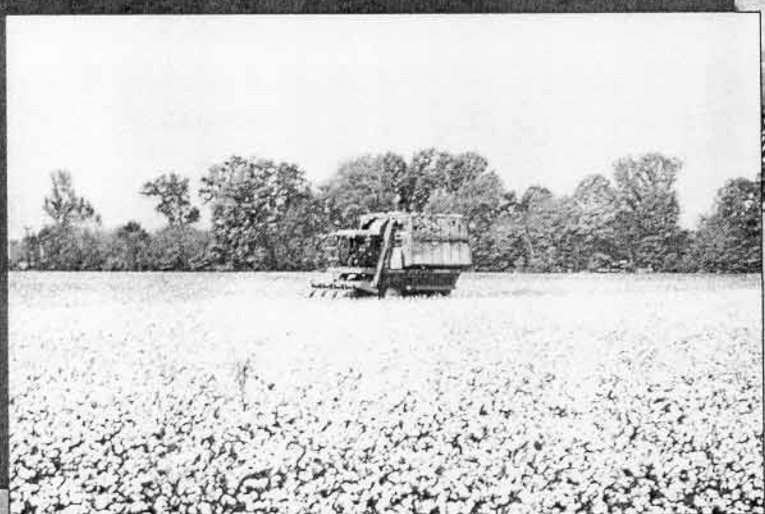

Conservation-Tillage Systems for Cotton

A Review of Research and Demonstration Results from Across the Cotton Belt

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COVER CROPS

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INTRODUCTION

In conservation-tillage systems, crop residues are left on the soil surface to reduce erosion potential. Residues after cotton harvest, however, can be insufficient for adequate soil protection (Mutchler et al., 1985). Growing winter-annual cover crops following a cotton crop can provide increased surface cover for erosion control.

The benefits of growing winter annual cover crops extend beyond erosion control. When used in a conservation-tillage system, cover crops increase soil organic matter, which will result in higher soil nitrogen (N) and water holding capacity. Legume cover crops can provide significant amounts of biologically fixed nitrogen to a succeeding cash crop. Also, weed control may be enhanced by the plant residues shading the midrows and by allelopathic chemicals (substances produced by one plant that inhibit other plants) present in a cover crop surface mulch.

Short-term economic returns from the use of cover crops for soil protection and improvement have not justified the cost of establishing the winter crop for many growers. Recent federal soil conservation legislation has sparked a renewed interest in cover crops. Reeves (1993) summarized the requirements of a cover crop in a conservation-tillage system. He noted that a cover crop should 1) be easy to establish, 2) have a rapid fall growth rate to provide adequate ground cover through the winter, 3) produce enough dry matter to maintain residues, 4) be disease resistant and not be a source of inoculum for diseases of cash crops, 5) be easy to kill and 6) be cost effective.

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COVER CROP SPECIES

Legumes

Hoyt and Hargrove (1986) reviewed the scientific literature on legume cover crops. They reported that crimson clover, vetch and Austrian winter peas can be widely grown in the Southeast, although other species may be more appropriate in specific situations. Since it is more cold tolerant, hairy vetch may be a better choice in the northern areas. Austrian winter peas are susceptible to rootknot nematode and may increase these pest problems.

Crimson clover is especially suited for a conservation-tillage cotton production system because it can reseed prior to planting the cotton crop in the spring, eliminating annual establishment of the winter cover. However, in some years, waiting for the clover to mature may cause a delay in cotton planting. This may reduce yield. Recently, a new clover cultivar named 'Robin' has been released by Auburn University. Robin is seven to 10 days earlier in maturity than 'Tibbee' and may reduce the risks involved with later planting following a reseeding crimson clover crop.

Research indicates that crimson clover, hairy vetch and Austrian winter peas can provide sufficient nitrogen for a succeeding cotton crop. Touchton et al. (1984) found that yields following crimson clover and hairy vetch without added N were similar to yields following winter fallow with 60 lb/acre added N (the optimum N rate in that experiment). In a three-year experiment conducted by Bauer et al. (1993), cotton ('Coker 315') yield did not increase when N fertilizer was applied following green-manured Austrian winter peas and crimson clover. Cotton yield following the legumes was similar to the yield of cotton in the fallow treatment that received 100 lb/acre of N fertilizer. At Blackville, South Carolina, hairy vetch provided adequate N to a succeeding full-season cotton crop in 1992 (Paul Porter, 1993, personal communication).

The amount of N from a legume cover crop is dependent on several management factors. In particular, those factors that promote growth of the cover crop, i.e., early planting in the fall or natural reseeding, adequate plant nutrients (other than N) and soil pH and late killing in the spring, will increase the amount of total N available to the cotton crop.

Since the N-supplying capacity of the legume cover crop residues is dependent on the biomass produced, nitrogen fertilizer may be needed in fields, or areas of fields, with poor legume growth for optimum cotton yield. Leaf N or petiole nitrate monitoring of the cotton crop can be used to identify N deficiency for areas needing additional N fertilizer.

Non-legumes

The main non-leguminous cover crops used are the winter cereals—wheat, rye and oats. Seed costs for wheat are generally lower than for the other two winter cereals. Rye is more cold tolerant than wheat or oats, so planting may be done later in the fall and still achieve adequate ground cover. Oats are resistant to Hessian fly.

The winter cereals offer several advantages over the legumes as cover crops. They are easy to establish and provide quicker ground cover in the fall. In general, they can be planted later in the fall and still provide adequate ground cover through the winter. Also, they are easily killed in the spring by herbicides.

Environmental concerns of nitrate contamination of groundwater have increased interest in the use of the winter cereals for cover crops. Shipley et al. (1992) found that use of a cereal rye cover crop resulted in less leaching of residual N fertilizer than use of legumes or winter weeds. Growing winter cereals to scavenge residual N fertilizer may be a promising technique to reduce non-point pollution potential to ground and surface waters.

The amount of residual N left after a summer crop will partially determine the growth of the non-legume winter cover crop. Therefore, in fields with little residual N, mixtures of legumes and non-legumes may provide optimum residues for greatest soil protection.

Incorporation of large amounts of plant residues from non-legumes may alter the amount of N fertilizer needed by a following cotton crop. In the decomposition of the residues, N will be tied up by soil microorganisms in a process called immobilization. An application of starter fertilizer that contains N may be necessary to avoid N stress in young cotton seedlings. Leaf N and/or petiole nitrate monitoring can be used to diagnose if N deficiency occurs later in the season.

ESTABLISHMENT PROBLEMS ASSOCIATED WITH THE USE OF COVER CROPS

Proper cover crop management is needed to insure that the harmful effects of cover crops do not outweigh their benefits. Cotton production systems that include the incorporation of significant amounts of decomposing plant residues into the root zone can create conditions that decrease stands, retard seedling growth, delay maturity and reduce cotton yields.

Reduced cotton stands in research plots containing cover crops have been attributed to 1) an increase in seedling disease (*Rhizoctonia solani*) following hairy vetch and crimson clover (Rickerl et al., 1988); 2) ammonia toxicity following incorporated alfalfa residues (Megie et al., 1967); 3) volatile compounds that are emitted from the residues during decomposition (Bradow and Bauer, 1992; Bradow and Connick, 1988); and 4) seedbed moisture depletion by the cover crop.

Cotton cultivars appear to differ in their susceptibility to the detrimental soil conditions associated with the use of legume cover crops as green manures. Bauer et al. (1991) grew five cotton cultivars following winter weeds or paraquat-desiccated and disc-incorporated crimson clover (Tibbee) and vetch ('Cahaba White') in 1988 and 1989. Stands of 'PD-3' were greatly reduced following crimson clover in 1988 but not in 1989 (Table 1). Crimson clover residues were associated with reduced stands of Coker 315 and 'PD-2' in both years of the study. Total seedcotton yields were not affected by cover crop treatment in either year, but maturity (measured as a percentage of total yield in the first harvest) was delayed both years in cotton grown following the legumes.

Since the yields of the five cotton genotypes were similar in conventional winter fallow and green manure plots, it appears that similar cultivar selection criteria can be used if delayed maturity will not be a yield limiting factor. However, it is important to note that in this study the legumes were incorporated more than two weeks before planting cotton. Yield reductions, due to reduced plant stands, can occur when cotton is planted before the recommended two- to three-week waiting period after green-manuring a legume.

For example, in another experiment in South Carolina conducted by Bauer and Bradow (unpublished data), fallow weeds or crimson clover were incorporated in early May. Two cotton cultivars (PD-3 and Coker 315) and one germplasm line ('PD-5246') were planted either seven or 14 days later. Plant stands of the cultivars were reduced by the legume cover more than 50% in the legume plots planted seven days after incorporation, but no reduction occurred when the legumes were allowed to decompose for 14 days before cotton was planted. First-picking yield was reduced in those plots with low stands.

Conventional tillage was used in these experiments to incorporate all plant parts. Research is needed to examine the inhibitory effects of legume cover crops on cotton in reduced-tillage systems that include incorporation of some of the legume (such as light disking). Unlike the conventional tillage used in this experiment, residues are not incorporated in no-tillage systems. The absence of decomposing shoot residues in the root zones of no-tillage systems will provide the benefits of using a cover crop without introducing all of the inhibitory factors.

In conservation tillage, stand establishment can be delayed if the cover crop depletes seedbed moisture. In a study during 1991 and 1992, Bauer and Green (unpublished data) compared a conventional cotton-production system (no cover crop, disk tillage) to reseeding crimson clover production system (in-row subsoiling was the only tillage). The clover was desiccated on 13 May 1991 and 15 May 1992. Cotton was seeded on 17 May 1991 and 20 May 1992. In 1991 seed-bed moisture was adequate in both production systems. In 1992 the clover depleted the soil moisture, and stand establishment was delayed (Fig. 1) until it rained. For non-irrigated cotton production, killing all vegetation (weeds or a cover crop) two to three weeks before planting in conservation-tillage systems will reduce the potential for seedbed moisture deficit.

TIME-DEPENDENCE OF INHIBITIONS ASSOCIATED WITH PLANT RESIDUES

Historical recommendations (Pieters and McKee, 1938) for handling green manures include a three-week interval between residue incorporation and cotton planting. Bradow and Bauer (1992) conducted laboratory studies that suggest that cotton planting should be delayed for two weeks or until no recognizable plant material remains.

The experiment involved growing cotton (Coker 315) seedlings for two weeks in soil collected immediately after cover (fallow weeds or crimson clover) incorporation (Day 0), seven days after incorporation (Day 7), 14 days after incorporation (Day 14) or 28 days after incorporation (Day 28). Growth of the cotton in these soil samples was compared to a **sterile** soil control in the form of greenhouse potting mix.

In 1991, cotton seedling root length from both the fallow and clover treatments from Day 0 and Day 7 was reduced by more than 50% compared to the sterile control. This root growth inhibition was accompanied by reductions of more 40% in root and shoot dry and fresh weights. The Day 0 clover and fallow soil samples also inhibited shoot elongation (more than 25%) and cotyledon expansion (more than 20%). These inhibitions of cotton seedling growth were even greater in 1992 when the time elapsed between soil sample collections and laboratory assay was minimized (Bradow, unpublished results).

The inhibitory effects of the decomposing residues of both the fallow weeds and crimson clover treatments in the laboratory assay disappeared with time. Although soils containing fallow weed residues, in comparison to sterile greenhouse soil, inhibited cotton seedlings in the laboratory assay, they did not have an observable influence in the field study.

The strong inhibition of cotton seedling growth by soil containing the residues of the weeds in the laboratory study was also not expected on the basis of relative weed and clover biomass. The mean dry weight of clover residues was 2600 lb/acre, and that for weed residues was 789 lb/acre. The fallow weed population, however, contained significant amounts of redroot pigweed (*Amaranthus retroflexus* L.) residues, which release volatile organic compounds that inhibit seed germination and seedling growth (Connick et al., 1989; Bradow and Connick, 1988, 1990).

ROLE OF VOLATILE COMPOUNDS EMITTED BY DECOMPOSING PLANT RESIDUES

Mixtures of simple organic compounds, many of them odor and flavor components (Bradow and Connick, 1990), are released by the decomposing residues of winter-cover legumes such as Berseem clover, hairy vetch and crimson clover. These volatile mixtures greatly inhibit germination of some small-seeded vegetable crops. In the laboratory, the mixture emitted by residues of Berseem clover reduced 'Deltapine 41' cotton seed germination more than 40%, and the emissions from Tibbee crimson clover residues caused a significant 20% seed germination reduction (Bradow and Connick, 1988). The volatile mixture from hairy vetch had no significant effect on cotton seed germination.

Individual compounds have been identified in the volatile emissions of the decomposing residues of amaranth weeds, crimson clover, hairy vetch and Berseem clover (Connick et al., 1987, 1989; Bradow and Connick, 1990). When minute amounts of several of the more active volatile compounds (methylketones) were injected into soil in which cotton seedlings were growing, seedling growth was significantly inhibited (Bradow, 1993). The degree of seedling growth inhibition obtained through injection of these known volatile emissions from plant residues was comparable to that observed in the field and in laboratory experiments involving volatile mixtures produced by weed and cover crop residues. The soil-injection experiments also indicate that genotype sensitivity to these volatiles differs (Bradow, unpublished data).

SUMMARY

The benefits of using cover crops for soil protection and improvement are well documented. However, proper management of the cover crop is needed to ensure optimum cotton production. For legumes, it appears that prevention of reduced cotton stands in tillage systems in which some residues are incorporated involves incorporating the cover crop a minimum of two weeks (until no recognizable plant residues remain in the soil) before planting cotton. Also, improving soil aeration will prevent accumulation of toxic volatiles and speed decay processes. The differing sensitivities of cotton genotypes to plant-residue volatile emissions suggest that the development of cotton cultivars is possible for the production systems that include incorporated legumes. For both legumes and non-legumes that are left as surface mulches, early killing of the cover crop is necessary to avoid seedbed moisture depletion unless irrigation is available.

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Table 1. Cotton stands following crimson clover or hairy vetch with current production recommendations. Data from Bauer et al., 1991.

	1988		1989
Cultivar	Crimson Clover	Hairy Vetch	Crimson Clover
	-------- Percentage of Fallow --------		
Coker 315	83	111	70
DPL 50	108	94	90
McNair 235	83	103	102
PD-2	81	103	77
PD-3	57	92	116
Fallow mean (plants/ft)	2.81		2.29

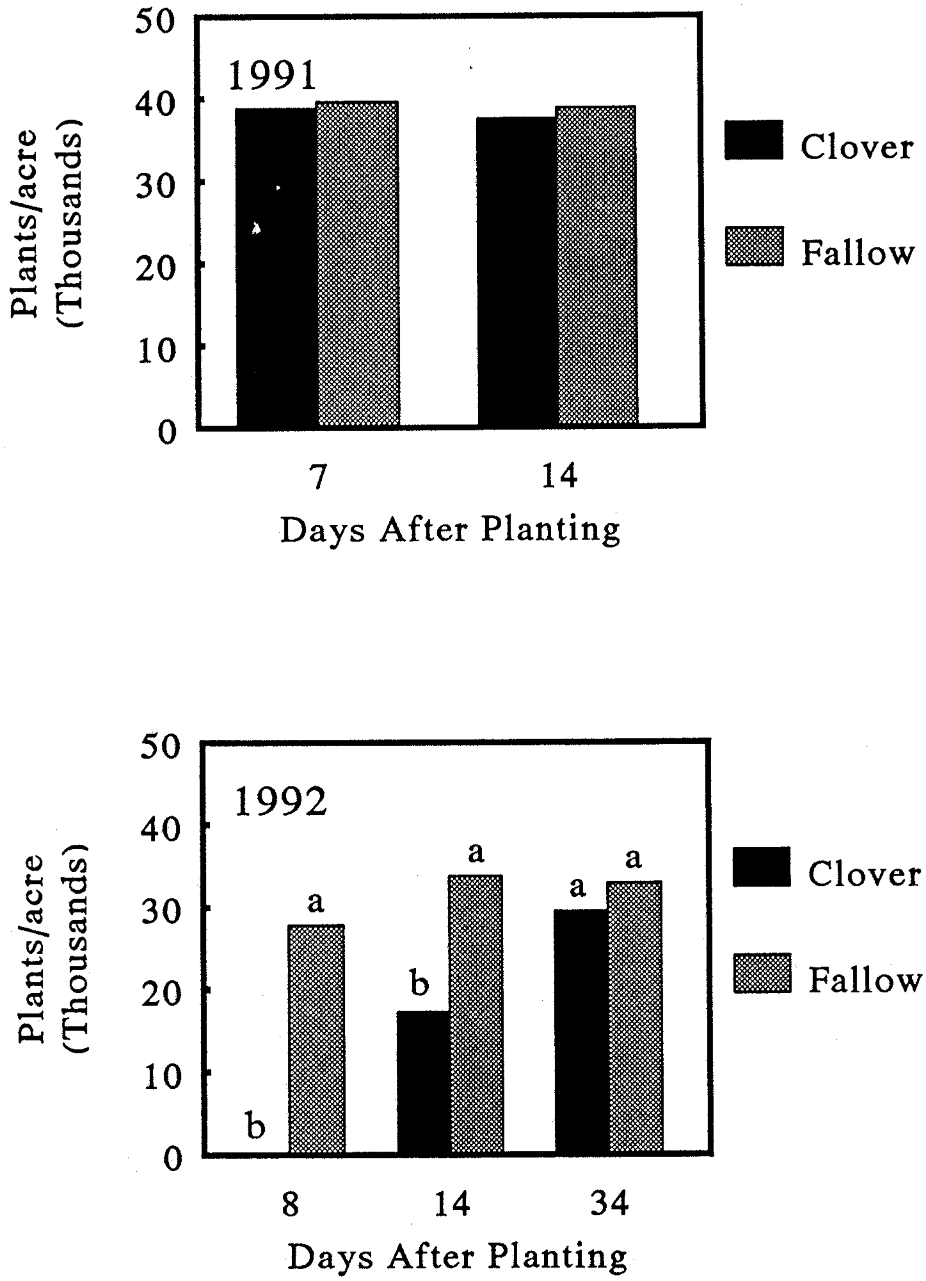

Fig 1. Comparison of a conventional production system (fallow) with a reseeding crimson clover cover crop system on cotton stand establishment at Florence, South Carolina, in 1991 and 1992. No differences in plant population were found between the two systems in 1991. In 1992 plant populations were significantly different (at the 95% probability level) at 8 and 14 days after planting.