WEED AND DISEASE MANAGEMENT

Role of cover crops in weed management and water quality

A. Douglas Worsham

Most of the benefits of cover crops are well known. They provide wind and water erosion control, conserve soil moisture by reducing evaporation and increasing infiltration, increase the content of organic matter, increase fertility by recycling nutrients, add nitrogen (N) if they are legumes, and improve soil structure. Certain cover crops can also improve weed control by increasing mulch and allelopathically suppressing weed growth and may improve environmental quality, especially through the protection of surface water and groundwater, by reducing or in some cases eliminating the need for preemergence herbicides.

The majority of row-crop acreage in the Southeast is on Coastal Plain soils, an area described by the U.S. Environmental Protection Agency as one with a high potential for leaching of pesticides into groundwater. The primary weed management system for the 72 million acres of corn in the United States is the preemergence application of a combination of atrazine and alachlor, which makes these two products the most widely used herbicides in the United States.

In preliminary surveys, detectable residues of both atrazine and alachlor have been found in a small percentage of water wells *(26)*. Programs designed to lessen the potential for groundwater contamination from pesticides have already been established and others seem inevitable *(31, 32)*. These programs may involve changes in use patterns, restrictions for certain areas or states, or canceling the registered uses for certain products.

For example, atrazine and atrazine-containing herbicides became restricted-use products on September 1, 1990 because of groundwater concerns. On October 24, 1990, the manufacturer of alachlor canceled its use in Florida because the cost of required groundwater tests made further sales in that state unprofitable.

The conservation provisions of the 1985 Food Security Act encourage owners of highly erodible cropland to fully implement approved conservation plans by January 1995. One means of achieving compliance in the Southeast will be the increased use of no-till planting. Greater use of cover crops will be required to meet conservation guidelines for soil protection at planting time (30% ground cover for most of the United States, 50% in North Carolina) *(29)*.

In this chapter, we will discuss recent developments in weed management for no-till crops planted into killed cover crops; the suppression of broadleaf weeds by certain cover crop mulches, and some possible reasons for this; and the implication for improvement of environmental quality, especially groundwater quality.

Weed suppression by cover crops

The presence of crop residues has been reported to both increase and decrease crop yields *(11)*. No-till has been reported to increase the presence of certain difficult-to-control weeds *(11)*. However, other reports indicate that the presence of certain mulches can reduce the biomass of weeds and allow for higher crop yields *(2, 17, 21, 28)*. Research to date indicates that both mulch and the lack of soil tillage contributes to the suppression of weeds in no-till cropping systems *(21)*.

Putnam and DeFrank *(16)* and Barnes and Putnam *(2)* used *Populus* wood shavings to separate chemical and physical effects of mulches. Their work indicated that certain mulches

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do possess allelopathic potential. We placed mulch on tilled soil after tillage. Tilling was performed to expose weed seeds to light and create other physical parameters conducive to germination. The results indicated that most of the suppression of weeds by wheat and rye mulch is allelopathic. Thus, research to date indicates that both mulch and the lack of soil tillage contributes to the suppression of weeds in no-till cropping systems *(21)*.

There are about 250 plant species sufficiently troublesome in agriculture to be termed weeds. In spite of modern weed control methods, even in developed countries that rely heavily on chemical herbicides for weed control, losses due to weeds are relatively high. In the United States, annual losses to weeds are estimated at 10% to 12% of total crop production *(4)*. More than 125 herbicides are now registered for use in the United States and growers spend about $3.6 billion annually on chemical weed control, about 65% of all United States pesticide sales. Total agricultural losses from weeds in the United States, including efforts to control them plus losses in yield and quality, are estimated at $10 to $16 billion per year. Until recently, weed management in no-till cropping systems has been somewhat difficult *(30)*.

Herbicides will continue to be a key component in most integrated weed management systems in the foreseeable future. Some problems and potential problems, however, are receiving increased attention and concern. Such problems include persistence in soil; contamination of the environment, especially groundwater; crop injury; an increase in herbicide-resistant weeds; increased costs of discovering and developing new herbicides; enhanced soil biodegradation; and container disposal.

Because of these problems and other potential ones, increased attention is being focused on alternative ways to control weeds. Allelopathic suppression of weeds as a possible alternative weed management strategy has received increased study in recent years *(1, 6, 28)*.

Crop and weed scientists traditionally have viewed allelopathic interactions in agriculture as detrimental *(18)*. Many weeds have been reported to have allelopathic properties that reduce crop growth and yield. In fact, 13 of the world's 18 worst weeds have been reported to produce allelochemicals *(14)*. Allelopathic potential has now been suggested for about 90 species of weeds *(15)*.

Table 1. Effects of small grain mulch and tillage on weed control at two locations over 2 years in North Carolina.

	Percent Weed Control	
*Mulch Type**	*Broadleaf†*	*Grass‡*
Rye	85ab#	70b#
Wheat	74c	61bc
Barley	75c	54bc
Oats	80bc	64b
None	63d	41d
None§	90a	81a

*All treatments had 6 pounds/acre diphenamid and 3 pounds/acre glyphosate applied to kill grain and provide residual weed control.

†Redroot pigweed, common lambsquarters, and commn ragweed.

‡Large crabgrass (*Digitaria sanguinalis* L.) and goosegrass [*Eleusine indica* (L.) Gaertin.].

#Means within a column followed by the same letter are not significantly different as determined by Waller-Duncan T-test (K ratio = 100). Ratings are in early-season. Modified from Shilling et al. (*19*).

§Tilled and rebedded prior to transplanting tobacco and cultivated twice.

In recent years, however, more attention has been given to possibilities of exploiting allelopathy to aid in weed management. This approach gains importance as we try to adopt crop production methods that rely less on high-chemical (pesticide) inputs *(28)*. Researchers have effectively used cover crops of wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), oats (*Avena sativa* L.), rye (*Secale cereale* L.), grain sorghum [*Sorghum bicolor* (L.) Moench], and sudangrass (*Sorghum sudanese* L.) to suppress weeds, primarily annual broadleaf weeds *(2, 16, 17, 19, 21)*. Weed suppression has also been noted in the United States from residues of several winter annual legume crops. White et al. *(25)* reported inhibition of several weeds from field residues and leachates of crimson clover (*Trifolium incarnatum* L.) and hairy vetch (*Vicia villosa* Roth). However, where legume residues were not incorporated, these authors believed the impact on weeds in legume no-till cropping systems would be minimal. Teasdale *(22)* showed some weed suppression from hairy vetch residues, but concluded that other methods of weed control would be needed. Enache and Ilnicki *(8)* concluded, however, that subterranean clover (*Trifolium subterraneum* L.) has a definite potential for controlling weeds in corn. Else and Ilnicki *(7)* studied growth and species composition of weeds in four mulch and tillage systems, with and without corn. A living subterranean clover mulch provided nearly complete weed control with or without corn. Evidence of allelopathic activity was found in extracts of clover leaves and in dead residue. Corn presence caused additional reduction in weed biomass in the other three treatments: a dead rye mulch, a common chickweed (*Stellaria media* L.) dead mulch, and tillage. Types of weed species were not affected by corn presence, but were affected by mulch. The authors concluded that some mulches can, in the presence of a corn crop, provide adequate weed control without the use of herbicides or mechanical control.

Among five no-till systems studied by Shilling et al. *(19)* using desiccated small grains for weed suppression, rye generally provided the best broadleaf weed control (Table 1). Rye has also been particularly effective in studies by Putnam and DeFrank *(16)*, Barnes et al. *(3)*, and Worsham *(27)*. The high-biomass production of shoots and roots, winterhardiness, and phytotoxicity of the residues make this grass crop effective in no-till soil conservation cropping systems.

Chou and Patrick *(5)* identified nine acids from ether extracts of decaying rye residues in soil. Eight of the nine—phenylacetic, 4-phenylbutyric, vanillic, ferulic, *p*-coumaric, *p*-hydroxybenzoic, *o*-coumaric, and salicylic acids—inhibited the growth of bioassay plants.

Two different groups of investigators isolated compounds from water extracts of aboveground rye mulch that inhibited weed growth in laboratory bioassays. Shilling et al. *(19, 20, 21)* found that ß-phenyllactic acid (PLA) and *p*-hydroxybutyric acid (HBA) provided 20% to 60% inhibition of common lambsquarters (*Chenopodium album* L.) and redroot pigweed (*Amaranthus retroflexus* L.). Barnes et al. *(3)* isolated two hydroxamic acids, 2,4-dihydroxy-1,4(2*H*)-benzoxazin-3-one

(DIBOA) and 2(3*H*)-benzoxyazolinone (BOA), with phytotoxicity on a large number of weed test plants. These two compounds were more phytotoxic than PLA or HBA, and DIBOA was shown to maintain toxicity for an extended period following addition to soil.

The collective allelochemical action of rye mulch on weed suppression in the field is outstanding. Barnes et al. *(3)* reported that weed biomass in a cover crop of living rye was reduced 90% over unplanted controls. A mulch of 40-day-old spring-planted rye gave 69% reduction. Shilling et al. *(21)* found rye mulch and root residues to give over 90% early season reduction in the biomass of common lambsquarters, redroot pigweed, and common ragweed (*Ambrosia artemisiifolia* L.) in no-till planted soybeans [*Glycine max* (L.) Merr.], sunflowers (*Helianthus annuus* L.), and tobacco (*Nicotiana tobacum* L.) compared with tillage and no rye.

Liebl and Worsham *(12)* reported significant reductions in morning-glory (*Ipomea* sp.) and prickly sida (*Sida spinosa* L.) in field studies involving wheat mulch and isolated ferulic acid as the most phytotoxic compound from foliar wheat extracts.

Weston et al. *(24)* investigated the apparent allelopathic effects of sudex [*Sorghum bicolor* (L.) Moench x *Sorghum sudanese* (P.) Stapf.] on weed and vegetable species. Two major phytotoxins, *p*-hydroxybenzoic acid and *p*-hydroxybenzaldehyde, were isolated and identified from shoot tissue. These compounds are potentially the enzymatic breakdown products of the cyanogenic glycoside dhurrin. Sudex tissue collected at 7 days of age possessed a greater percentage of these phytotoxins on a per gram basis than did older sudex tissue. As the tissue age increased, the percentage of *p*-hydroxybenzaldehyde in ether extracts of tissue also increased, while the percentage of *p*-hydroxybenzoic acid decreased.

Recent discoveries concerning microbial transformation of certain allelochemicals from wheat and rye may be significant in increasing phytotoxicity of these residues to weeds. Liebl and Worsham *(12)* reported that ferulic acid in the presence of prickly sida seed carpels was decarboxylated by a bacterium living on the seeds to a styrene derivative, 2-methoxy-4-ethenylphenol. The new compound was more phytotoxic to prickly sida than ferulic acid and may play an important role in control of this weed in natural conditions under wheat mulch.

More recently, Nair et al. *(13)* isolated a microbially transformed allelochemical, 2,2'-epidioxy-1,1'-azobenzene [2,2'-oxo-1,1'-azobenzene] (AZOB) from a soil supplemented with BOA. AZOB was more toxic to curly cress (*Lepidium sativum* L.) and barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] than either DIBOA or BOA. Although there were no detectable amounts of the biotransformation product in soil under rye residues, the implications of such phytotoxic biomagnification of allelochemicals may be very significant in helping to explain allelopathic weed suppression under field conditions.

Although there is great promise in using cover crops and mulches to aid in weed control, much research is needed to gain full advantage of the system. Some problems that need attention are the lack of suppression of perennial weeds and annual and perennial grasses, the cost of establishing and killing the cover crop, allelopathic effects on the crop itself; and compatibility of rotations.

Table 2. Effect of straw management and tillage on weed suppression in no-till planted crops in North Carolina (*28*).*

	Percent Weed Control†	
Straw and Tillage Treatment	*Rye Mulch*	*Wheat Mulch*
Remove straw and till soil	9a‡	30a‡
Remove straw, no-till	43b	50b
Remove straw, till and replace	60c	60c
Leave straw, no till	76d	81d

*Average results from research in corn, soybeans, sorghum, and tobacco, 1980-1986.
†Early-season ratings on redroot pigweed, common lambsquarters, common ragweed, morningglory sp., prickly sida, sicklepod.
‡Means within a column followed by the same letter are not significantly different as determined by Waller-Duncan T-test (K-ratio = 100).

Table 3. The effects of mulch, tillage, and diphenamid (*N, N*-dimethyl-α-phenyl benzeneacetamide) on weed control in flue-cured tobacco at two locations in North Carolina (*19*).

	Percent Weed Control*	
Treatment	*Broadleaf†*	*Grass‡*
Tilled, no herbicide	8e§	47c§
Tilled, plus herbicide	52d	67bc
No-till, no herbicide	68bc	71abc
No-till, plus herbicide	87ab	94a
No-till, rye mulch, no herbicide	79bc	54bc
No-till, rye mulch plus herbicide	97a	80ab

*Ratings taken four weeks after transplanting.
†Redroot pigweed, common lambsquarters, and common ragweed.
‡Goosegrass and large crabgrass.
§Means within a column followed by the same letter are not significantly different as determined by Waller-Duncan T-test (K-ratio = 100).

Results of work in North Carolina

Our work in North Carolina over a number of years indicates that leaving a small grain mulch and no-till gives 75% to 80% early season control of a number of annual broadleaf weeds (Table 2). Removing straw, tilling, and replacing straw gives 60% control. Removing straw and no-till gives 40% to 50% control, and removing straw and tilling the soil, without herbicides, gives little to no control of these weeds (Table 3). We concluded that no-till accounted for some weed control, but having straw alone contributed even more. No-till used with a straw mulch gave the highest degree of weed control.

Shilling et al. *(19)* reported research in which they attempted to partition the weed control effects from tillage alone, no-till, and no-till plus mulch with and without a preemergence herbicide in tobacco (Table 3). Tillage alone without herbicide gave 8% early season control of broadleaf weeds and 47% control of annual grasses. Adding a soil-applied herbicide gave 52% and 67% control of broadleaf weeds and grasses, respectively. No-till, without herbicide or mulch, gave 68% and 71% control. The no-till treatment without mulch plus herbicide yielded 87% and 94% control. Rye mulch alone, no-till without herbicide gave 79% and 54% control, respectively, of broadleaf and grass weeds, and rye mulch plus herbicide in no-till gave 97% and 80% control. Results from the same treatments with wheat, oats and barley were similar. These results confirm the need for no-till plus having a mulch to achieve the highest degree of weed control without a preemergence herbicide.

In a 1989 study to determine the difference in weed suppressing ability of a number of rye cultivars, we found that after rye kill, no additional herbicides were needed for weed control in no-till corn, soybeans, or grain sorghum. In 1990, however, weed control from the rye mulch alone was not adequate *(9)*.

In a preliminary study in 1990, redroot pigweed control 4 weeks after planting no-till corn, cotton, soybeans, or tobacco was 81% in rye, 79% in subterranean clover, 72% in crimson clover, 41% in hairy vetch, 39% in no-cover no-till, and 0% in conventionally tilled plots. No preemergence or postemergence herbicides were used. Postemergence herbicides were needed later in the season for complete weed control for most crops.

Can you rely entirely on allelopathy for weed control? Producers interested in reducing or eliminating chemical inputs in cropping systems often ask if the allelopathic cover crops or mulches will do the whole weed control job so herbicides would not be needed.

Our experience in North Carolina indicates that, most of the time, herbicides are still needed, especially postemergence herbicides in late-season. The allelopathic-suppression effect usually is adequate only for the first few weeks for a crop.

In research plots, however, we have been able to grow corn, soybeans, grain sorghum, and sunflowers and attain adequate weed control with only a heavy mulch of killed rye. We killed the rye cover before planting with an herbicide.

Often, producers ask if the cover crop can be used without killing it, or if there is a way to kill it without using a herbicide. First, the cover crop has to be killed or greatly suppressed so that it will not compete detrimentally with the planted crop. There are some alternatives to using herbicides. We have successfully killed small grain cover crops by mowing. For this to be effective, however, the crop has to be near maturity so that it does not grow back. Later-planted crops, such as soybeans or grain sorghum, can be planted after the small grain or annual legume cover crops mature naturally. Some success has been noted with using sweeps to mechanically kill legumes in bands for planting (personal communication, Larry King, Soil Science Department, North Carolina State University, Raleigh). Planting a crop one year, such as sorghum or spring oats, that will be winter-killed, leaves a dead mulch for planting into the next spring.

Environmental implications

As described in this chapter, many cover crops temporarily suppress annual broadleaf weeds; there is evidence that this suppression may eliminate the need for preemergence soil-applied herbicides at the time of planting summer crops, which has several benefits. First, the cost of extra herbicide application is eliminated. The potential for groundwater contamination is lessened because herbicides used to kill the cover crops are foliar applied and do not leach into the soil. Postemergence herbicides will probably still be required for the crops, but these, if needed, are usually used at much lower rates than preemergence herbicides, less will reach the soil, and most have low to very low groundwater contamination potential, according to the ranking index by Weber *(23)*.

Hoag *(10)* used a model for evaluating groundwater contamination potential by changing to a postemergence weed management approach for soybeans. Using his cost-environmental hazard predictive model, changing from the most herbicide-intensive, environmentally risky system to an environmentally desirable postemergence herbicide only, the groundwater-risk potential was reduced by 65% at no extra cost to the producer. Further risk reduction was possible at very little cost. The new selective postemergence herbicides for corn should allow great reduction in environmental risk and groundwater contamination potential for this major-acreage crop also.

There are disadvantages and potential problems with the use of cover crops. Some of these include the cost of establishment; difficulty in killing cover crops, especially legumes; leaching of nitrates from legumes; lowering of soil temperatures in spring; depleting soil moisture in the spring, the unknown effects of releasing natural phytotoxins into the environment; and possibly increasing certain insects and diseases.

More research is needed on the extent to which cover crops that are allelopathic to weeds can be substituted for preemergence herbicides. More research is especially needed to determine the factors influencing the degree of weed suppression, as results are variable now. Finally, more research must be done to provide the information needed to help growers integrate these new practices into on-going crop production practices and rotations.

Conclusions

Weed control is usually achieved in conventionally tilled crops mainly through cultural, mechanical, or chemical practices. Because weed control options are limited with the adoption of no-till cropping practices, the difficulty of controlling weeds is often cited as a problem in no-till crop production. However, environmental and ecological differences that distinguish no-till from conventional tillage may benefit growers by enhancing control of certain weed species in no-till cropping systems. With the proper choice and management of cover crops and plant residues, it may be possible to supplement, if not reduce, the number and amount of herbicides used in these cropping systems, particularly preemergence herbicides. Eliminating tillage restricts weed seeds to poor-germination sites, and by using natural phytotoxic substances leaching from plant residues, the germination of seeds and growth of many weeds is inhibited through allelopathy. It has also been shown in at least two examples, that microbial activity in soil has converted allelochemicals into derivatives more toxic to weed development.

Many researchers have found that use of certain cover crops suppresses weeds to the extent that herbicides are not needed. This would result in a substantial reduction of environmental contamination potential, especially for groundwater supplies. With the other well-known benefits of cover crops that can benefit the environment, such as wind and water erosion control, nutrient recycling, this new potential will continue to help make our water clean and keep it clean.

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Mechanical control of legume cover crops

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Burndown herbicide costs inhibit the use of winter cover crops in no-till cropping systems *(6)*. Some legumes are particularly difficult to kill with glyphosate or paraquat *(1, 4)*. There is a growing interest in developing conservation tillage systems with decreased herbicide usage.

Research in Louisiana comparing legume responses with mowing or treatment with glufosinate, glyphosate, or paraquat in mid-April indicated considerable variation among cover crops *(1)*. Mowing effectively killed several vetches, crimson clover, and wheat, but not others, such as subterranean clover. Atrazine applied 2 weeks later resulted in effective control of many legumes not controlled by mowing or low-rate burndown herbicide treatments alone *(2)*. Eastman *(3)* found that rolling using a no-till grain drill with coulters and cast-iron press wheels spaced 4.75 inches apart was as effective as mowing in killing both crimson and subterranean clovers (late-April, late-bloom growth stages). The coulters cut stems lying on the ground while the press wheels crushed the stems.

The objectives of our study were (a) to determine the effectiveness of flail mowing or rolling with coulters in killing several legume cover crops at three growth stages between early April and early May and (b) to evaluate the effectiveness of atrazine in killing previously mechanically treated or untreated legume cover crops.

Methodology

We conducted field experiments in northern Mississippi during 1989 and 1990. We evaluated four legumes, 'Tibbee' crimson clover (*Trifolium incarnatum* L.), 'Mt. Barker' subterranean clover (*T. subterraneum* L.), 'Bigbee' berseem clover (*T. alexandrinum* L.), and hairy vetch (*Vicia villosa* Roth) at three treatment dates: early-April (March 28, 1989 and April 4, 1990); mid-April (April 13, 1989 and April 20, 1990); and early-May (May 2, 1989 and May 4, 1990). We either cut each cover crop at 1.5 inches aboveground with a flail mower or rolled each with coulters spaced either 4 or 8 inches apart. We also included a mechanically untreated plot for each date. Two weeks after mechanical treatment, we treated all plots with atrazine plus crop oil at 2 pounds active ingredient plus 1 quart/acre. We arranged the experiment as a randomized complete block split-plot design with four replications. Main plots were treatment dates and subplots were cover crop/mechanical treatment combinations in a strip-block layout. We applied mechanical operations in 10-foot wide strips perpendicular to 13-foot wide legume strips.

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At each mechanical treatment date, biomass samples were taken from duplicate 1-square-foot areas of each legume strip. We also determined decumbent stem length (length lying along the ground), canopy height, and growth stage on at least three representative plants. We rated percent control on a 0 to 99 scale at approximately weekly intervals following the initial mechanical treatment and following subsequent treatments with atrazine. We subjected control rating data to an arcsine transformation *(5)* prior to analysis of variance (ANOVA) and means separations. We excluded killing ratings for mechanically untreated areas prior to atrazine application (zero values) from ANOVAs to avoid underestimations of experimental errors.

Results and discussion

The cover crops differed in period of maximum growth, flowering time, and canopy structure (Table 1). Crimson clover produced the most aboveground dry matter, but added only a small amount after mid-April. Berseem clover added the most dry matter after mid-April. Subterranean clover and hairy vetch had less dry matter than crimson clover at each date. Crimson and subterranean clovers were in full bloom by mid-April, while hairy vetch and berseem clover remained vegetative until early-May or later. Hairy vetch had the longest stems. Subterranean clover had a compact canopy structure with much of its stem length lying close to the soil. Despite erect growth habits, crimson and berseem clovers had considerable decumbent stem length by early May.

Two weeks after mechanical treatments, effectiveness of cover crop killing was flail mowing > 4-inch coulter > 8-inch coulter (Table 2). Mowing killed 87% to 94% of crimson

Table 1. Two-year mean cover crop dry matter, growth stage, canopy stage, canopy height, and decumbent stem length at three sampling dates.

Cover Crop	*Early April*	*Mid-April*	*Early May*
Aboveground dry matter (pounds/acre)			
Hairy vetch	2,060b*	3,680b	4,550b
Crimson clover	2,460a	6,410a	6,820a
Subterranean clover	1,820b	3,300b	4,800b
Berseem clover	1,980b	3,750b	6,390a
Growth stage†			
Hairy vetch	0.00c	0.00b	1.35b
Crimson clover	0.87a	3.00a	4.12a
Subterranean clover	1.75b	3.25a	4.12a
Berseem clover	0.00c	0.00b	0.00c
Canopy height (inches)			
Hairy vetch	11.0b	14.4b	21.0a
Crimson clover	13.3a	17.6a	16.4b
Subterranean clover	4.8c	7.1c	9.0c
Berseem clover	14.4a	19.2a	24.5a
Decumbent stem length (inches)			
Hairy vetch	10.2a	17.4a	23.5a
Crimson clover	2.0c	6.3c	10.9c
Subterranean clover	6.0b	10.3b	17.6b
Berseem clover	1.7c	1.1d	10.8c

*Values within a column and a subgroup followed by the same letter are not significantly different (P = 0.05).

†Based on rating scale: 0-vegetative; 1-<10% bloom; 2-11 to 50% bloom; 3->50% bloom; 4-pods and/or immature seed; 5-mature dry seed.

Table 2. Two-year mean cover crop kill ratings 2 weeks after mechanical treatment on three dates and 2 weeks after treatment with atrazine (4 weeks after mechanical treatment).

	Cover Crop Kill Ratings by Mechanical Treatment*			
			Coulter Spacing	
Treatment Date	*None*	*Flail Mow*	*4 Inches*	*8 Inches*
2 weeks after mechanical treatment				
Hairy Vetch				
Early April	0	94a†	80b	62c
Mid-April	0	91a	90a	73a
Early May	0	99a	99a	98b
Crimson Clover				
Early April	0	87a	44b	23c
Mid-April	0	88a	83ab	56b
Early May	0	99a	93b	81b
Subterranean Clover				
Early April	0	41a	26ab	16b
Mid-April	0	45a	26b	21b
Early May	0	90a	61b	42c
Berseem Clover				
Early April	0	64a	20b	13c
Mid-April	0	51a	31b	26b
Early May	0	93a	53b	35b
2 weeks after treatment with atrazine				
Hairy Vetch				
Early April	94c	98a	98ab	97b
Mid-April	99a	99a	99a	99a
Early May	97b	99a	99a	99a
Crimson Clover				
Early April	93b	99a	94b	93b
Mid-April	96b	99a	99a	99ab
Early May	99a	99a	99a	99a
Subterranean Clover				
Early April	69c	97a	87b	81b
Mid-April	87c	99a	97ab	93bc
Early May	96b	99a	98a	98a
Berseem Clover				
Early April	68b	99a	73b	75b
Mid-April	72c	98a	84b	76bc
Early May	88b	99a	91b	89b

*Based on a scale of 0 to 99 with 0 = no control and 99 = completely killed.
†Values within a row and subgroup followed by the same letter are not significantly different (P = 0.05).

clover and hairy vetch at the early and mid-April treatments dates and killed at least 90% of all cover crops at early May. Rolling with a 4-inch coulter spacing when decumbent stem lengths exceeded 10 inches killed 80% to 100% of hairy vetch and crimson clover, but killed only 53% of berseem and 26% to 61% of subterranean clovers. Results with the 8-inch spacing followed trends similar to the 4-inch treatment, but were less effective.

All mechanical treatments increased atrazine kill of the cover crops (Table 2). Mowing followed by atrazine resulted in at least 97% control of all cover crops at all dates. At the mid-April and early May treatments, rolling with the 4-inch coulter spacing was as effective as mowing for all cover crops except berseem clover. Rolling with the 8-inch coulter spacing was also effective at these dates for crimson clover and hairy vetch. With no mechanical pretreatment, atrazine plus oil controlled hairy vetch and crimson clover, but was less effective on subterranean and berseem clovers.

Control of all cover crops was easier after early or mid-April. For crimson and subterranean clovers, the increased susceptibilities coincided with seed formation and completion of normal life cycles. In contrast, berseem clover and hairy vetch were vegetative or at first-bloom in early May. We attributed their increased susceptibilities primarily to increasing stem length and location of active buds only near the stem apices.

These studies indicate that mechanical methods may be sufficient to control cover crops in some situations. Even where control is incomplete, mechanical treatment may so weaken the cover crop that normal preemergence herbicides can complete the control process. Thus, mechanical measures may be substituted for burndown herbicides in stands without significant populations of weeds not controllable by these treatments.

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Cover crop management for soybean production in northern Missouri

Z. R. Helsel, N. C. Wollenhaupt, and K.D. Kephart

More than 30% of the over 4 million acres of soybeans [*Glycine max* (L.) Merr.] planted in Missouri are grown in continuous soybean rotation. Because almost all of these acres are tilled, most upland soybean fields are eroding at a rate greater than allowed by the conservation compliance legislation. Crop rotation is not feasible due to lack of adequate feed grain and/or wheat base, and in addition, soybeans are the most profitable crop grown in this claypan soil-type region *(5)*. Planting soybean fields to a cover crop could be an option for meeting conservation compliance soil erosion standards. Other virtues ascribed to cover crops could add to their profitability in crop production *(3, 4)*.

Investigators have identified some successful cover crop management practices for regions that receive more spring precipitation than northern Missouri *(1)*. Used in conjunction with characteristics of shallow soils, it is not clear how applicable these practices are for cover crop establishment, soil erosion reduction, and other benefits, such as weed suppression in this region.

The objective of our study was to evaluate the feasibility of overseeding small grain cover crops into standing soybeans. We designed the research to answer important applied questions, including (a) optimum time for establishment, (b) amount of cover produced, (c) winter hardiness, (d) ease of suppression prior to row-crop planting, and (e) weed suppression potential.

Methods

We established the experiment at five locations across northern Missouri in the fall of 1988: Columbia, Palmyra, Novelty, Chillicothe, and Corning. We overseeded winter wheat (*Triticum aestivum* L.), winter rye (*Secale cereale* L.), and spring oats (*Avena sativa* L.) into standing soybeans at early leaf drop (early September), mid-leaf drop (mid-September), and at harvest (early October). Soybean residue without a cover crop treatment served as our control treatment plot.

We used three methods to control the cover crop and/or weeds at two dates, late-April (6-inch cover growth) and early May (late-boot stage). The treatments were mowing only, glyphosate only, and glyphosate plus imazaquin plus alachlor. We measured aboveground cover and surface residue in late-fall and at planting using a point frame. We made weed control ratings 4 weeks after the soybeans had been planted. We harvested soybean plots for yield at the Columbia location. The experimental design was a split-split block.

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Results and discussion

The following results and discussion represent the first year of a 3-year study. We achieved successful establishment of wheat and rye cover crops at all three fall overseeding dates when the soil was moist and/or rainfall occurred within 2 weeks after seeding. Due to below-average rainfall, fall cover crop growth (measured in December) contributed less than 20% additional ground cover. Oat establishment was inconsistent. Soil moisture at seeding time and rainfall appear to be more important for cover crop establishment than seeding date in this region.

Soybean residue alone produced 50% or more ground cover, measured at planting for all locations. We practiced conservation tillage in establishing the 1988 soybean crop at all locations. We measured two-year-old residues (1987 crop) of corn stover, wheat straw, and soybean stems at planting (spring 1989) in amounts ranging from 10% to 15%. The cover crops added substantial amounts of residue but only accounted for an additional 10% to 20% increase in ground coverage. Despite the substantial amount of previous crop residue, following a high-intensity rainstorm at Columbia after soybean emergence, only the plots with wheat and rye residue maintained adequate erosion protection until canopy closure.

Cover crop control and weed suppression evaluations produced a number of observations. Mowing in late-April was not effective in controlling rye and wheat. At the early May date, wheat was in the late-boot stage and rye was just beginning to head. Mowing at this date resulted in about 80% kill. Mowed wheat and rye provided better weed control than the soybean residue checks without cover crops. It is believed that cover crop weed suppression is due to competition for light, water, and/or allelopathy. At most locations the weed control benefit was offset by cover crop regrowth. In other words, the cover crop became a yield-limiting pest. Mowed cover crops combined with drought resulted in a crop failure at two locations.

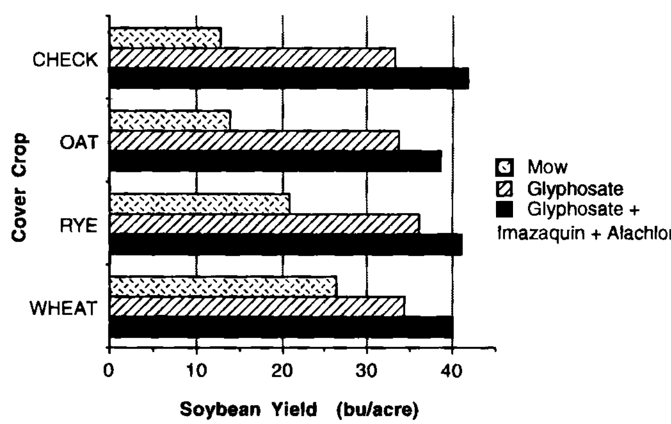

Figure 1. Soybean yields as influenced by cover crop type and methods of controlling cover crops and weeds, Columbia, Missouri.

Rye and wheat depressed soil moisture levels to the near-wilting point in the top 12 inches of soil at planting time. We experienced similar results with small grain cover crops in Iowa *(2)*. This could be beneficial in wet springs but, as previously noted, is detrimental in a dry spring.

Glyphosate was very effective in controlling cover crops and the existing weeds on both dates of application. Glyphosate with preemergence soil-applied herbicides effectively controlled cover crops and all spring and summer weed growth.

We harvested the Columbia plots to learn how cover crop types, spring cover crop control, and weed management practices might effect soybean yields (Figure 1). (Note that we cultivated all plots in late-June.) Although soil moisture at planting was approaching wilting point for the mowed cover crop treatments, the soil profile was completely recharged by a series of rainstorms that occurred a few days after planting. Soybean yield differences are therefore likely related to weed control or lack thereof, including cover crop regrowth.

The soybean residue check plots without herbicides averaged 13 bushels/acre. Rye and wheat cover crop plots without herbicides (mow treatments) averaged 21 and 26 bushels/acre respectively. Soybean residue check plots with glyphosate and no cover crop yielded 33 bushels/acre. Cover crop plots treated with glyphosate resulted in about the same yield level. We measured the highest yield (42 bushels/acres) in the soybean residue check plot with glyphosate plus a soil-applied herbicide. The addition of a cover crop did not increase nor decrease yield.

Because soybean yields were comparable with or without cover crop plus a soil-applied herbicide, the economic justification for use of cover crops will be based on the value of participation in U.S. Department of Agriculture programs, reduced soil erosion, and reduction of off-site impacts including water quality. Managing cover crops to minimize water stress on subsequent crops poses a substantial constraint to farmer acceptance of cover crops in this region.

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Effects of a winter rye cover crop system and available soil water on weed control and yield in soybeans

D. D. Warnes, J. H. Ford, C. V. Eberlein, and W. E. Lueschen

Concerns about soil erosion, water quality, and the use of synthetic agricultural chemicals have increased interest in the development of more sustainable cultural systems for soybean [*Glycine max* (L.) Merr.] production.

Use of winter rye (*Secale cereale* L.) as a cover crop could help reduce erosion, improve the physical condition of soil, increase water penetration *(1)*, and help control weeds through competition and allelopathic effects *(2)*. A limitation of a winter rye cover crop system in Minnesota may be the lack of adequate soil water to support growth of both the cover and the soybean crop. Therefore, the objective of our research was to determine the effects of a fall- or spring-planted winter rye cover crop on weed control, soybean yield, and available soil water.

Methods and materials

We conducted field studies from 1985-1990 at Morris, Lamberton, and Waseca, Minnesota, to evaluate the use of a winter rye cover crop system for weed control in soybeans. Each fall, we no-till planted winter rye into small grain stubble, or prepared a seedbed by fall-plowing and cultivation. The following spring, we killed the winter rye with glyphosate (0.5 pounds/acre) 2 days prior to planting soybeans no-till into the rye residue. We allowed spring-planted winter rye to grow for 6 weeks and then killed it with glyphosate (0.5 pounds/acre) 2 days prior to planting soybeans no-till (10- or 30-inch spacing) into the rye residue. No further cultivation was performed.

We visually evaluated percent weed control. We harvested grass and broadleaf weeds from a 2-foot by 2-foot area, separated, dried, and converted it to pounds per acre of weed dry matter. We harvested soybeans with a small plot combine and measured seed yield. We analyzed weed control and yield data using analysis of variance, and compared means using Fisher's least significant different (LSD) at the 0.05 level of significance. The studies conducted at Morris were on Doland silt loam (4%-5% organic matter) (fine, loamy, mixed, Udic Haploboroll); at Lamberton on Normania silt loam (5%

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Table 1. Effect of fall- or spring-planted winter rye cover crop on weed and soybean yield at Morris, Minnesota, 1985-1989.

	Weed Yield					Soybean Yield				
Treatment	1985	1986	1987	1988	1989	1985	1986	1987	1988	1989
	pounds dry matter/acre					bushels/acre				
Fall rye, gly 2 db*	150	697	814	0	510	54	40	25	0	39
Spring rye, gly 2 db†	430	449	965	0	738	39	32	33	2	36
Weedy check	1,103	2,699	9,329	8,976	3,888	27	2	8	0	17
Hand-weeded check	57	136	22	0	6	51	36	36	17	45
LSD $\alpha = (0.05)$						5	11	5	4	7

*Fall-planted rye, glyphosate 2 days before no-till planting soybeans.
†Spring-planted rye, allowed to grow 6 weeks, glyphosate 2 days before planting soybeans.

organic matter) (fine, loamy, mixed, Mesic Aquic Halplustoll); and at Waseca on Webster clay loam (7% organic matter) (fine, loamy, mixed, Typic Haplaquoll).

We determined available soil water in the top 5 feet of the soil profile by gravimetric soil sampling in the fall prior to establishing these experiments. During the growing season, we determined available soil water by using a neutron soil probe. We used official U.S. National Weather Service records from each location for precipitation data.

Results and discussion

Field studies conducted from 1985-1989 indicate that soybeans were tolerant of the winter rye cover crop system when available soil water was adequate (Table 1). The fall-planted winter rye system resulted in soybean yields equal to the hand-weeded check at Morris in 1985 and 1986, when precipitation was above-average. However, we obtained slightly lower to significantly lower yields with the rye system at Morris in 1987, 1989, and 1990; and at Waseca in 1989 when conditions were dry. In 1988, soybean yields ranged from 0 to 4 bushels/acre because of severe drought at Morris and Lamberton.

The spring-planted winter rye system produced soybean yields nearly equal to the hand-weeded check at Morris in 1986 and 1987, but resulted in significantly lower yields than hand-weeded check in 1985 and 1989. The winter rye cover crop controlled weeds for a period of time after we had killed the winter rye with the glyphosate treatment. Weed control by winter rye, which was the result of both allelopathy and competition, ranged from 50% to 90% (Table 1). Fall-planted rye provided a greater reduction in the weed dry matter yield than the spring-planted rye at Morris in 1985, 1987, and 1989. In heavy weed-infestation plots at Waseca in 1988 and 1989, soybean yields were significantly reduced in the winter rye system due to lack of adequate weed control (Table 2).

Neutron probe readings for available soil water showed that in June the fall- and spring-planted winter rye system had 2.2 and 0.9 inches, respectively, less soil water than the hand-weeded check. The early-fall and late-fall planted winter rye in 1990 had 3.3 and 1.1 inches, respectively, less available soil water than the handweeded check (Table 3).

We calculated the relative soybean yield as yield from the fall rye treatment divided by yield of the hand-weeded check and compared it to available soil water levels (Figure 1). We calculated available soil-water status by adding fall soil moisture plus precipitation from April 1 to June 30. Locations eliminated from this comparison were the Waseca 1988 and 1989 sites because of heavy weed infestations and the Morris 1987 site because fall available soil water was not determined. About 15 inches of available water were needed to produce soybean yields in the winter rye system equal to the hand-weeded check. Soybean yields were severely reduced when available soil water was less than 10 inches. In years with over 20 inches available water, the fall-planted winter rye cover crop system may be beneficial because it removes excess soil moisture.

Variable precipitation and high weed pressure are the major risks associated with using a winter rye cover crop system for soybean production. Minimizing moisture stress in

Table 2. Effect of fall-planted winter rye cover crop system on soybean yield at Morris, Waseca, and Lamberton, Minnesota, 1988-1990.

	Soybean Yield								
				Waseca					
	Morris			Heavy Weeds		Light Weeds		Lamberton	
Treatment	1988	1989	1990	1988	1989	1988	1989	1988	1989
	bushels/acre								
Fall rye, gly 2db*	0	23	27	10	17	38	42	4	25
No rye, gly 2db†	0	18	24	7	12	37	46	6	39
No rye, herbicide check‡	2	10	32	9	33	32	46	9	34
Weedy check	0	11	18	6	1	31	29	0	21
Hand-weeded check	14	29	32	25	41	45	48	15	47
LSD $\alpha = (0.05)$	3	9	5	9	9	15	8	5	16

*Fall planted rye, glyphosate 2 days before no-till planting soybeans.
†No winter rye, glyphosate 2 days before no-till planting soybeans.
‡Herbicide check with no rye, alachlor (3 pounds/acre) + metribuzin (0.25 pounds/acre).

Table 3. Available soil water in winter rye cover crop-soybean system at Morris, Minnesota on June 29, 1989 and June 7, 1990 in top 0 to 5 feet of soil profile.

	Available Soil Water (inches)	
Treatment	1989	1990
Fall-planted rye, gly 2db*	2.0	
Spring-planted rye, gly 2db†	3.3	
Early fall-planted rye, gly 2db‡		4.1
Late fall-planted rye, gly 2db§		6.3
Hand-weeded check	4.2	7.4

*Fall planted winter rye, glyphosate 2 days before planting.
†Spring planted winter rye, grown for 6 weeks, glyphosate 2 days.
‡Early fall (September 1) planted rye, glyphosate 2 days before planting.
§Late fall (October 15) planted rye, glyphosate 2 days before planting.

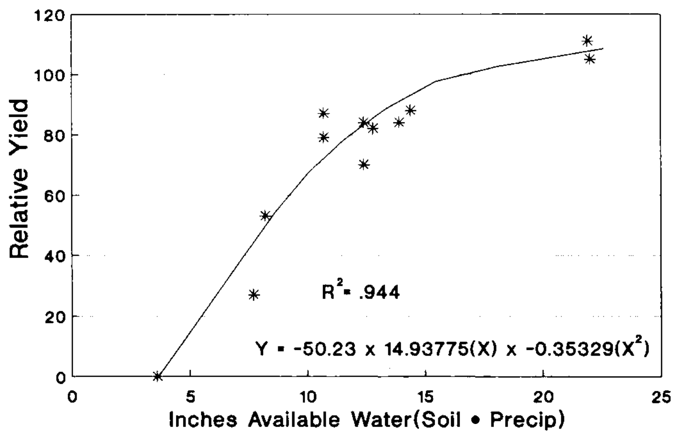

Figure 1. Effect of available water in inches (fall soil + spring precipitation) on soybean yield (fall rye treatment as a percentage of hand-weeded check).

the soybean crop will require additional research on managing the winter rye cover crop to conserve moisture. As dates of planting and killing of the rye are changed to reduce moisture stress on the soybeans, there will be a greater reliance on postemergence herbicides and cultivation for weed control. Additional cover crops should be evaluated for their potential to reduce wind and water erosion, to control weeds, and to produce minimal stress on the soybean crop.

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Weed management in corn polyculture systems

Jane Mt. Pleasant and Thomas W. Scott

The use of cover crops following corn has not been a common practice for the last 20 to 30 years in New York. Those farmers that do use cover crops usually seed rye (*Secale cereale* L.) following corn harvest. Fall establishment of legume cover crops has not been successful because of the short time between seeding and the onset of below-freezing weather. Although rye grows well in cool weather, late-fall seeding can result in crop failure over winter.

Winter cover can be established by interseeding forage legumes and grasses in corn early in the growing season (at cultivation). Like traditional cover crops, interseedings reduce erosion and add organic matter to the soil. Interseeded legumes can also contribute nitrogen (N) to the cropping system *(4)*. Forage species growing in the field at corn harvest may recycle excess nitrates (NO_3) in the soil profile that would otherwise be lost through leaching. Many species, such as ryegrass (*Lolium* spp.), medium red clover (*Trifolium pratense* L.), alsike clover (*Trifolium hybridum* L.), hairy vetch (*Vicia vollosa* Roth), yellow sweetclover [*Melilotus officinalis* (L.) Pall], and white clover (*Trifolium repense* L.), have been successfully introduced into continuous corn systems at cultivation time in the northeast. If seedings are made when the corn is at least 6 to 8 inches tall, they do not reduce corn yields through competition *(4)*. A complicating factor in their use, however, is weed management. Many herbicides used on corn would also control the interseeded species. Wide use of interseedings requies effective and practical weed management strategies. A narrow-band application of herbicide over the corn row in combination with one or two cultivations has proved effective in controlling weeds in New York *(1)*. This weed management practice would be compatible with the use of interseedings because herbicide is applied in a 10-inch band over the corn row, which leaves the remainder of the between-row area chemical-free. There is also evidence that interseeded forages may actually reduce weed levels in continuous corn by preventing late-season weed invasions *(2)*.

We established a field experiment with the following objectives: (a) determine if band application of herbicide plus cultivation controls weeds in corn interseeded with red clover or ryegrass and (b) to determine the effects of these interseedings on weed infestations.

Methodology

We established an experiment to assess the effects of interseeded red clover or ryegrass on the N status of a succeed-

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Table 1. Effects of interseeding and weed control on corn grain yields and weed cover, Aurora Research Farm.

Cropping System	Grain Yield (bushels/acre)	Weeds		Interseeded Species
		% cover		
1988			October	
Corn monoculture, broadcast herbicide	105	11.8		-
Corn monoculture, band herbicide + cultivation	100	33.2		-
Corn interseeded red clover, band + cultivation	111	23.4		10.8
Corn interseeded ryegrass, band + cultivation	96	22.1		27.7
LSD 0.05	NS	4.8		
1989			October	
Corn monoculture, broadcast herbicide	111	3.1		-
Corn monoculture, band herbicide + cultivation	108	28.5		-
Corn interseeded red clover, band + cultivation	111	10.0		32.1
Corn interseeded ryegrass, band + cultivation	108	11.9		11.8
LSD 0.05	NS	2.0		
1990			July	
Corn monoculture, broadcast herbicide	99	2.4		-
Corn monoculture, band herbicide + cultivation	98	22.4		-
Corn interseeded red clover, band + cultivation	104	16.3		7.2
Corn interseeded ryegrass, band + cultivation	97	15.8		15.3
LSD 0.05	NS	3.2		

ing corn crop at the Aurora Research Farm in 1987. We modified this experiment in 1988 in order to examine weed management practices in interseeded corn. The original experiment used a split-plot design with 4 N levels (subplot) and 5 seeding years for red clover or ryegrass (mainplot). Two monoculture corn treatments were also included. We replicated treatments four times. Subplot size was 10 feet by 40 feet.

In 1988, we applied the following weed control treatments: corn monoculture, broadcast herbicide; corn monoculture, band herbicide plus cultivation; corn interseeded with ryegrass, band herbicide plus cultivation; and corn interseeded with red clover, band herbicide plus cultivation. Data presented are from 3 years of the experiment (1988, 1989, and 1990) and have been summed over N levels and years of seeding.

We planted corn cultivar 'Pioneer 3737' each year following conventional tillage, in 30-inch rows and using soil-test recommendations for phosphorus (P) and potassium (K) fertilization. We applied atrazine (1 pound active ingredient/acre) and pendimethalin (1.5 pounds active ingredient/acre) in a 10-inch band over the row or broadcast. We broadcast seeded Arlington medium red clover and 'Grimalda' perennial ryegrass following cultivation at 12 and 16 pounds/acre, respectively, about 6 weeks after corn emergence each year. We evaluated weed populations in October 1988, October 1989, and July 1990, using a beaded string method *(5)*. We identified weeds by species and then grouped them for analyses as grass, broadleaf, or sedge. We took corn grain yields from 30 feet of the two center rows of each subplot.

Results and discussion

Table 1 gives corn grain yields and percent cover for interseeded species (red clover and ryegrass) and weeds. Corn grain yields were not affected by interseeding or weed control practice. The level of weed cover, however, differed among treatments. Corn monoculture with broadcast herbicide had the lowest percent weed cover each year. Band herbicide plus cultivation increased weed levels in both monoculture and interseeded corn, but interseeded corn had less weed cover than monoculture corn with the same weed control practice.

Interseeded species ranged in percent cover from 7.2% (red clover in July 1990) to a high of 32% (red clover in October 1989). There were large variations in the stands of interseeded species, but the amount of cover provided by interseedings in a particular year was not correlated with weed cover in that year. Neither was there a correlation between interseeding cover in the fall of the year and weed cover in the subsequent year.

These data show that band herbicide plus cultivation is a viable weed management strategy in a corn polyculture system. Although weed levels were higher with this practice, weeds did not reduce corn grain yields even when interseeded species were well established, providing substantial cover. Weed levels in the corn polyculture system were less than in corn monoculture using the same weed control practice. The mechanism for this reduction in weed levels is unknown.

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Cover crop effects on weeds, diseases, and insects of vegetables

Sharad C. Phatak, Robert L. Bugg, Donald R. Sumner, J. Danny Gay, Kathryn E. Brunson, and Richard B. Chalfant

Weeds, diseases, nematodes, and insects cause substantial quality and yield losses in vegetables in the southern United States. Pesticides registered for use in vegetable production are limited, and more registered pesticides are withdrawn from the market each year. Also, there is major consumer concern about pesticide residues in fresh produce as well as in the environment.

Cover crops are important components in many agricultural systems because they can improve soil structure, reduce erosion, and improve productivity *(4, 9)*. Except where conservation tillage is practiced, producers usually employ cover crops as green manures and incorporate them into the soil by disking *(11)*. In doing so, however, other potential benefits may be lost. Conservation tillage is not currently used in vegetable production in the southern United States, but this general approach offers excellent prospects.

Weeds cause substantial loss in vegetable production. In Georgia alone, such losses exceed $6 million annually *(5)*. Properly managed cover crops can suppress many weeds through shading or allelopathy *(6, 7, 8)*. Soilborne pathogenic fungi and nematodes limit vegetable production in the Southeast *(10)*. Root-knot nematode (*Meloidogyne incognita*) and other nematodes may cause severe yield losses *(10)*. In Georgia alone, vegetable crop losses from soil insects, aphids, and thrips exceed $100 million annually *(3)*. Producers need information on the effect of sequences involving cool-season cover crops and vegetable crops on weeds, diseases, nematodes, and insects that affect yield and quality of vegetables.

We report here the results of an ongoing multidisciplinary study on a broad range of cool-season cover crops and their effects on weeds, diseases, nematodes, yield, and fruit quality in subsequent minimum-tillage cucumber plantings (*Cucumis sativus* L., *Cucurbitaceae*).

Methodology

To optimize horticultural consequences, we conducted multidisciplinary studies on a broad range of prospective cover crops in vegetable crop production systems. We planted cucumbers (*Cucumis sativus*, L., 'Comet') following overwintering cover crops. In replicated field trials, we assessed 20 different treatments with controls, on cover crop effects on incidence of weeds, insects, diseases, and nematodes.

We evaluated effects of cover crops on yield and quality of subsequent cucumber plantings. Cover crops evaluated included the following grasses (*Poaceae*) planted in monoculture: ryegrass (*Lolium multiflorum* Lamarck, 'Gulf Annual'); and rye (*Secale cereale* L., 'Wrens Abruzzi'). Brassicaceae evaluated in monoculture were mustard (*Brassica hirta* Moench, 'Florida Broadleaf'); turnip (*Brassica campestris* var. rapa L., 'Purple Top White Globe'); a turnip-Chinese cabbage hybrid (*Brassica campestris* var. rapa L. x *B. pekinensis* [Loureiro], 'Tyfon'); canola (*Brassica napus* L., 'Dwarf Essex'); and collard (*Brassica oleracea* L., 'Georgia'). Fabaceae considered in monoculture were sweet blue lupin (*Lupinus angustifolius* L., SNLL-87); fenugreek (*Trigonella foenum-graecum* L.); 'Cahaba White' vetch (*Vicia sativa* L. x *V. cordata* Wulf); 'Vantage' vetch (*V. sativa* x *V. cordata*); hairy vetch (*V. villosa* Roth, 'W67-HU-704'); common lentil (*Lens culinaris* Medic, 'Chilean 78'); subterranean clover (*Trifolium subterraneum* L., 'Mt. Barker'); crimson clover (*T. incarnatum* L., 'Dixie'); berseem clover (*T. alexandrium* L., 'Bigbee'); and arrowleaf clover (*T. vesiculosum* Savi, 'Yuchi').

We used the following two bicultural mixes: ryegrass and crimson clover; and ryegrass and hairy vetch. The final treatment was a control, which received no seeds. We visually rated plots for ground cover due to cover crops and weeds. During early May, we strip-killed cover crops with glyphosate herbicide and mowing, and seeded the cucumber crop using minimum-tillage methods. We applied no pesticides in 1988, and only made two applications of fungicides in 1989. Fertilizer applications were substancially reduced.

Results

In the principal study, fenugreek and Tyfon both failed to develop adequate stands; we excluded the corresponding plots from consideration.

Weeds. All cover crops but canola, fenugreek, and Tyfon attained adequate stands. We obtained particularly high fresh weights per unit area for arrowleaf clover, crimson clover, and mustard, and especially high dry weights occurred for rye, crimson clover/ryegrass biculture, and arrowleaf clover. Significant differences in ground cover from overwintering cover crops resulted in differences in weed control (Table 1).

Diseases. Densities of propagules of *Pythium* spp. were particularly high following Cahaba White vetch and ryegrass; and low following canola, control, subterranean clover, and Tyfon. No differences were found for *Rhizoctonia solani*. By contrast, we detected differences for *Rhizoctonia*-like binucleate fungi; propagule densities were particularly high for subterranean clover and turnip and particularly low for canola, ryegrass, and Vantage vetch. Densities for *Laetisaria arvalis* differed significantly among cover crop regimes. Densities were particularly high on collard, subterranean clover, and rye and especially low on the control, crimson clover, hairy vetch, ryegrass, subterranean clover, turnip, and Vantage vetch. We detected no differences in densities of propagules for an orange basidiomycetes.

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Table 1. Effect of cover crop ground cover on weeds and cucumber yield.

Cover Crop	*Ground Cover (%)*	*Weed Cover (%)*	*Cucumber Yield (pounds/acre)*
Ryegrass	94 ± 5	3 ± 2	11,815efg
Rye	59 ± 1	1 ± 0	21,101abcde
Mustard	48 ± 1	3 ± 1	19,452abcde
Turnip	48 ± 6	1 ± 0	12,568efg
'Tyfon'			21,213abcde
Canola	54 ± 6	5 ± 2	6,004gh
Collard	66 ± 8	2 ± 1	4,179h
Blue lupin	94 ± 1	1 ± 0	30,931a
'Cahaba White' vetch	100 ± 1	0 ± 0	23,823abcd
'Vantage' vetch	100 ± 1	1 ± 0	30,131a
Hairy vetch	100 ± 1	1 ± 0	14,409cdef
Hairy vetch/ryegrass	100 ± 1	0 ± 0	10,182fgh
Lentil	95 ± 2	3 ± 2	31,444a
Subclover	100 ± 0	3 ± 2	15,818cdef
Crimson clover	99 ± 1	0 ± 0	28,946ab
Crimson clover/ryegrass	100 ± 0	0 ± 0	20,301abcde
Berseem clover	98 ± 2	0 ± 0	22,814abc
Arrowleaf clover	98 ± 2	0 ± 0	17,739bcdef
Fenugreek			17,995bcde
Control		39 ± 14	12,936def
P*	0.0001	0.0001	0.0001
Fisher's PLSD†	9.197	9.821	

*Based on F-tests for effects due to crop using one-way ANOVA.
†For each date, pairs of means that differ by less than Fisher's protected least significant difference are deemed not significantly different.

Nematodes. There were no significant differences among cover crops for any of the pest nematodes observed (stubby-root, root-knot, lesion, spiral, and ring nematodes) at planting time. However, the cucumber crop planted following some legume cover crops was severely infested with southern root-knot nematodes.

Insects. There were significant differences in populations of beneficial and pest insects. Other entomological aspects of this study are detailed elsewhere *(1, 2)*.

Yield. We obtained especially high yields of marketable cucumber fruit following blue lupin, Vantage vetch, lentil, and crimson clover; we observed relatively low yields following ryegrass, turnip, canola, collard, and the hairy vetch/ryegrass biculture (Table 1). Relatively high percentages of rotten fruit (total rotten) occurred following several *Trifolium* and *Vicia* species, whereas the two grasses and three fallow regimes showed rather low percentages. Our present studies indicate both beneficial and risky relationships between cover crops and vegetable crops represented by cucumber. Critical studies conducted indicate that the cover crops/vegetable crops production program is feasible and beneficial for agroecosystems.

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Suppression of black root rot on cotton by winter legume cover crops

C. S. Rothrock and S. R. Kendig

A study initated in 1972 at the Delta Branch Station, Clarkedale, Arkansas, demonstrates that when planted as a winter cover crop, hairy vetch (*Vicia villosa* Roth) alone or in combination with rye (*Secale cereale* L.) increases cotton (*Gossypium hirsutum* L.) yields and improves soil properties compared with cotton monoculture *(11)*. Economic analysis of a hairy vetch-cotton cropping system from a long-term study in Louisiana indicated this cropping system was economical based on nitrogen (N) contribution from the cover crop alone *(3)*. Estimates of N contribution from a hairy vetch cover crop for a subsequent cotton crop ranged from 30 to 60 pounds N/acre *(2, 6, 13)*.

There is limited information on the impact of cover crops on pest populations and pest damage for the subsequent cash crop. This aspect is critical for cotton, a crop in which profitability is determined, in large part, by pest damage and pesticide use. Previous research reported fewer plants killed by Phymatotrichum root rot and increased cotton yields following incorporation of either hubam (*Melilotus alba* Medik. var. *annua* H.S. Coe) or indica [*Melilotus indica* (L.) All.] clover cover crops *(5)*. Researchers have also demonstrated that cover crops suppress diseases on other crops *(1, 4, 7)*.

In this chapter we present field and controlled environmental studies on the suppression of *Thielaviopsis basicola*, the pathogen causing black root rot of cotton, by winter legume cover crops.

Methodology

We conducted field studies in 1989 and 1990 on a long-term cover crop site at the Delta Branch Station, Clarkedale. The soil at this site is a fine silty loam and is a Dubbs-Dundee complex. We established the cover crop treatments, vetch, vetch plus rye, crimson clover (*Trifolium incarnatum* L.) plus rye, and winter fallow, by broadcasting seed of the cover crops and cultivating after the first cotton harvest. We incorporated cover crops about 3 weeks before planting cotton, and reestablished the rows with a hipper and disk harrow. We fertilized plots with 52 and 42 pounds N/acre in 1989 and 1990, respectively. We managed cotton according to current production recommendations *(11)*.

We assayed soil populations of *Thielaviopsis basicola* from preplant, planting, and 6-week postplant samples by the dilution pour plate method with the selective medium TB-CEN *(12)*. We sampled seedlings from five random 1-foot sections of nonyield rows. Seedlings were assessed for disease severity, then surface disinfested with 0.5% sodium hypochlorite and plated on TB-CEN medium to determine disease incidence.

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We also examined the influence of incorporating vetch on soil populations of *Thielaviopsis basicola* in a controlled environmental study. Soil taken from winter fallow plots of the long-term Clarkedale study were left unamended or were amended with 0.15% (low) or 0.5% (high) levels of hairy vetch, equivalent to 2,000 and 6,600 pounds/acre of cover crop on a dry weight basis. We maintained the soils at 68°F with a soil moisture of -0.3 bars, and assayed for populations of *Thielaviopsis basicola* at 3, 14, 21, and 28 days.

Results and discussion

Thielaviopsis basicola is one of the major pathogens of the cotton seedling disease complex at this site. Soil populations were significantly lower following the cover crop treatments of hairy vetch or hairy vetch plus rye than the winter fallow treatment at all sampling times (Table 1). The crimson clover plus rye cover crop treatment resulted in slight suppression of soil populations for the sample at cotton planting. The importance of reduced populations of this pathogen following these cover crops is indicated by the low incidence of black root rot on cotton for these treatments (Table 1). In addition, root discoloration was lower than the winter fallow treatment in 1990 for treatments containing vetch, a year when *Pythium* spp. were a minor component of the disease complex, indicating disease severity also had decreased following this cover crop (data not shown).

Thielaviopsis basicola populations were suppressed in soils amended with hairy vetch in a controlled-environment study

Table 1. Influence of cover crop treatments on *Thielaviopsis basicola* at Clarkedale, Arkansas.

Treatment	Propagules by Sampling Time: Preplant	Plant	Postplant	Disease Incidence (%)
	— 1,000 propagules/lb soil —			
Cover crop				
Winter fallow	57a*	60a	83a	29a
Crimson clover + rye	44a	29b	65a	14b
Hairy vetch + rye	23b	23b	30b	11bc
Hairy vetch	13b	15b	15b	2c
Year				
1989	39a	52a	91a	17a
1990	44a	30b	29b	20a

*Means followed by the same letter within a column and main effect are not significantly different (P = 0.05) LSD.

Table 2. Influence of hairy vetch amendments on soil populations of *Thielaviopsis basicola*.

Amendment Level (%)	Propagules by Days After Incorporation: 3	14	21	28
	—— 1,000 propagules/pound soil ——			
0	62a*	173a	254a	191a
0.15	70a	117ab	148b	175a
0.50	64a	35b	22c	33b

*Means followed by the same letter within a column are not significantly different (P = 0.05) LSD.

(Table 2). No change in population levels occurred within 3 days after amending soils. Suppression of *Thielaviopsis basicola* by the low-amendment level was less effective than the high-amendment level, and populations for the low-amendment level were equivalent to the unamended treatment after 28 days. The high-amendment level significantly reduced soil populations of the pathogen throughout the study. These results agree with previous research, indicating organic amendments were successful in the suppression of *Thielaviopsis basicola* in the control of bean root rot *(8, 9)*. The high-amendment level was greater than the amount of residue incorporated in a normal field situation. However, this treatment may more accurately reflect the impact of the annual incorporation of vetch or vetch plus rye cover crops on *Thielaviopsis basicola* over a number of years.

The results indicate that legume cover crops are effective in suppressing *Thielaviopsis basicola*, an important soil-borne pathogen. However, this pathogen is only one component of the seedling disease complex of cotton *(10)*. We will have to examine the impact of cover crops on pests and pest damage before integrated crop management systems can be developed that take advantage of pest-suppressing aspects of cover crops while minimizing any risks from increased pest damage.

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