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Cover Crop Management and Weed Control in Corn (*Zea mays*)[1]

GREGG A. JOHNSON, MICHAEL S. DEFELICE, and ZANE R. HELSEL[2]

Abstract. Field experiments were conducted in central Missouri in 1989 and 1990 to evaluate weed control practices in conjunction with cover crops and cover management systems in reduced tillage corn. There was no difference in weed control among soybean stubble, hairy vetch, and rye soil cover when averaged over cover management systems and herbicide treatments. However, mowed hairy vetch and rye covers provided greater weed control in the no-till plots than soybean stubble when no herbicide was used. Differences in weed control among cover management systems were reduced or eliminated when a PRE herbicide was applied. Corn population and height were reduced by hairy vetch and rye soil cover. Corn grain yield was reduced in rye plots both years. There was no difference in grain yield between tilled and no-till plots. **Nomenclature:** Hairy vetch, *Vicia villosa* Roth #[3] VICVI; rye, *Secale cereale* (L.); soybeans, *Glycine max* (L.) Merr.; corn, *Zea mays* (L.) 'Pioneer 3379'.

Additional index words: No-till, atrazine, glyphosate, *Secale cereale*, *Setaria faberii* Herrm., SETFA; *Vicia villosa*, *Xanthium strumarium* L., XANST.

INTRODUCTION

No-till crop production has several advantages over conventionally tilled systems. No-tillage reduces soil erosion, energy requirements, evaporation, and runoff (11, 14). However, producers are still reluctant to adopt no-tillage. The main reasons for producer dissatisfaction are real or perceived inadequate weed control and reduced crop yields with no-tillage (10). No-tillage crop production requires intensive weed management. Weed management systems with no-tillage crops may include a preplant herbicide, one or two PRE herbicides and possibly a POST herbicide to control weeds (9).

A concern with no-tillage is the shift in weed populations (18, 21). Weed population changes seem to favor small-seeded species in no-till whereas large-seeded broadleaf species diminish as a problem in no-till (1, 8, 22). One advantage of tillage is to kill weeds that emerge prior to planting, thus allowing the crop to have a competitive advantage (16). With no-tillage crops this must be accomplished with a preplant or preemergence herbicide.

No-tillage crop yield potential is considered equal to or greater than that of tilled crops (14, 19). Differences in soybean yield between conventional and no-till are often due to inadequate weed control rather than tillage (2).

One method to reduce the dependence on herbicides for weed control is the use of cover crops. Cover crops have been used to control erosion, contribute nitrogen, and control weeds. No-tillage, cover crops, and herbicides are being explored as ways to comply with the soil conservation programs currently required on highly erodible land. Many different cover crops have been used; however, the most extensively used is annual rye (12). Hairy vetch, clovers (*Trifolium* spp.), and wheat (*Triticum aestivum* L.) have also been evaluated. Cover crops are most effective when killed in the spring to create a mulch on the soil surface (4, 14). However, hairy vetch and rye can compete with corn if not controlled (3). Grain yields are usually not decreased by the cover crop if the legume or grass cover is suppressed or controlled (7).

The most common herbicides used for controlling or suppressing a living cover in the spring are paraquat (1,1′-dimethyl-4-4′-bipyridinium ion) and glyphosate [N-(phosphonomethyl)glycine]. There have been problems with incomplete control of cover crops, especially hairy vetch. Glyphosate does not completely kill hairy vetch (6, 20). However, when atrazine [6-chloro-*N*-ethyl-*N*′-(1-methylethyl)-1,3,5-triazine-2,4-diamine] or cyanazine {2-[[4-chloro-6-(ethylamino)-1,3,5-triazin-2-yl]amino]-2-methylpropanenitrile} was mixed with

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[3]Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available from WSSA, 309 W. Clark St., Champaign, IL 61820.

Table 1. Monthly rainfall amounts over the growing season at the Bradford Research Farm.

Month	1989	1990	30-yr average
	cm		
March	5	14	8
April	5	7	10
May	13	28	11
June	20	24	10
July	14	27	9
August	20	10	7
Total	77	110	55

glyphosate, hairy vetch was controlled or greatly suppressed.

Rye mulches have been shown to reduce broadleaf and grass weeds (15, 21). Hairy vetch also suppresses weeds. However, weed suppression by a legume cover crop was observed to be less than that provided by a small grain cover (13).

The use of cover crops in no-tillage can potentially reduce the cost of weed control, and minimize surface runoff of pesticides while reducing soil erosion. This study was conducted to evaluate cover crops for weed suppression potential, different levels of weed control inputs, and tillage and herbicides for cover crop management in corn production.

MATERIALS AND METHODS

Field experiments were conducted in 1989 and 1990 at the Bradford Agronomy Research Center near Columbia, MO. The soil was a Mexico silt loam (Udollic Ochraqualfs; fine montmorillonitic, mesic) with a pH of 6.6, 2.6% organic matter, and soil textural fractions consisting of 7% sand, 75% silt, and 18% clay.

There was above-normal monthly rainfall both years (Table 1). Rainfall in 1990 was abnormally high throughout the growing season, especially early in the growing season.

The experimental design was a split-split plot with four replications. Main plots were three soil covers; fall-planted winter rye, fall-planted hairy vetch, and soybean stubble from the previous year. Subplots were cover management systems which consisted of tillage, herbicide burndown, or rotary mowing. Sub-subplots were individual herbicide treatments.

'Balboa' annual rye in the main plots was hand-seeded at a rate of 157 kg ha^{-1} during early soybean leaf-drop on Sept. 20, 1988 and Sept. 11, 1989. Hairy vetch was hand-seeded at 22 kg ha^{-1} on Sept. 20, 1988, and at 28 kg ha^{-1} on Sept. 11, 1989. However, hairy vetch did not germinate as expected after initial seeding in 1989 and was reseeded on Nov. 11, 1989 at 28 kg ha^{-1} with a no-till drill. Hand-seeding of hairy vetch and rye was used to simulate aerial seeding.

Tilled plots in the cover management system were prepared prior to planting by chisel plowing to a depth of 15 cm followed by two passes with a disk. Plots were chisel plowed 2 d prior to planting and again at planting in 1990 due to wet soil conditions. Rye plots were rotary mowed prior to chisel plowing to improve ease of tilling. Mowed subplots were prepared just prior to planting with a rotary mower set at 8 cm cutting height.

The experimental plots were fertilized just prior to planting with 196 kg ha^{-1} of nitrogen as urea both years. Herbicide no-till plots were sprayed with glyphosate at 1.7 kg ae ha^{-1} 3 d prior to planting corn. A 0.5% v/v non-ionic surfactant[4] was added to glyphosate and tank-mixtures containing glyphosate. 'Pioneer 3379' corn was planted at 58 500 seeds ha^{-1} on Apr. 24, 1989 and Apr. 26, 1990 using a no-till planter equipped with ripple coulters.

Sub-subplots were 3 m side by 11 m long and consisted of four corn rows spaced 75 cm apart. The herbicide treated sub-subplot received a PRE application of alachlor [2-chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxymethyl)acetamide] and atrazine at 2.2 kg ai ha^{-1} and 2.2 kg ai ha^{-1}, respectively. The second sub-subplot was untreated. Glyphosate was applied on no-till subplots only.

Herbicides were applied with a CO_2-pressurized backpack sprayer calibrated at 207 kPa pressure to deliver 187 L ha^{-1} spray volume through 8002[5] flat fan nozzles. Glyphosate, and tank-mixtures containing glyphosate, were applied at 97 L ha^{-1} spray volume through 8001 flat fan nozzles.

Visual ratings were made for percent weed control (stand and growth reduction, top growth necrosis) 8 wk after herbicide application. Common cocklebur, *Xan-*

[4]X-77 Nonionic-type spreader and activator. Principal functioning agents: alkylaryl polyoxyethylene, free fatty acids, glycols, isopropanol. Constituents effective as spray adjuvant-90%. Constituents ineffective as spray adjuvant-10%. Valent U.S.A. Corp., 1333 N. California Blvd., P.O. Box 8025, Walnut Creek, CA 94596.

[5]Teejet 8001 and 8002. Spraying Systems Co., North Ave., Wheaton, IL 60188.

Table 2. Influence of soil cover, cover management, and herbicide treatment on weed control, corn stand, corn height, and grain yield[a,b].

	Weed control									
	SETFA		XANST		Corn stand		Corn height		Grain yield	
Treatment	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990
	%				plants per 22 m row		m		kg ha^{-1}	
Cover:										
Rye	57 b	69	75	76	81 b	47 b	1.9 b	2.0 c	3840 b	1740 b
Hairy vetch	63	65	79	63	78 b	69 a	1.9 b	2.4 b	4400 ab	4820 a
Soybean stubble	45	63	68	60	88 a	77 a	2.3 a	2.5 a	5850 a	5330 a
Cover management:										
No-tillage	50	51 b	68 b	65	88 a	55 b	2.1 a	2.3	4690	3850
Tilled	49	80 a	60 b	69	86 a	78 a	2.1 a	2.3	5110	3940
Mowed	67	66 ab	95 a	64	73 b	61 b	1.9 b	2.3	4290	4110
Herbicide:										
PRE[c]	93 a	90 a	99 a	86 a	90 a	70 a	2.4 a	2.5 a	7990 a	5940 a
Untreated	17 b	41 b	49 b	46 b	74 b	59 b	1.7 b	2.1 b	1400 b	1990 b

[a]Means in the same column followed by the same letter are not significantly different according to Fisher's Protected LSD Test ($\alpha = 0.05$). Letters must be compared only within main and subplot effects.

[b]Columns without letters are not significant.

[c]Alachlor + atrazine at 2.2 + 2.2 kg ai ha^{-1}. Glyphosate added to the mixture in the no-tillage plots at 1.7 kg ae ha^{-1}.

thium strumarium L., # XANST; and giant foxtail, *Setaria faberii* Herrm., # SETFA; were the dominant weed species present. A rating of 100 = complete death of the plant whereas 0 = no visual injury to a plant. Weed control ratings were evaluated against the treatment that had the greatest weed infestation. The tilled soybean stubble plots that did not receive a herbicide treatment had the greatest weed infestation in 1989. The greatest weed infestation in 1990 occurred in mowed soybean stubble plots that did not receive a herbicide.

Corn height was measured at tasseling on six plants selected at random in the center two rows of each plot and heights were averaged. Corn stand counts were obtained by counting all plants in the center two rows. Corn grain yield was obtained by mechanically harvesting the center two rows of each plot. Harvest dates were Sept. 29, 1989 and Sept. 25, 1990. Seed weight was corrected to 15.5% moisture content.

All data were subjected to the appropriate analysis of variance. Visual control ratings were subjected to an arcsin transformation to normalize variance. Mean separation was calculated with Fisher's Protected LSD Test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

There was no difference in visible weed control between the main effects of soil covers in 1989 or 1990 (Table 2). However, a significant interaction between soil cover and cover management was observed for giant foxtail control in 1989 and common cocklebur control in 1990 (Table 3). Giant foxtail and common cocklebur control was greater in mowed rye and hairy vetch covers than in soybean stubble when averaged over herbicide treatments. Mowing tended to provide greater giant foxtail control than no-tillage or tillage in rye and hairy vetch covers (Table 3).

Mowed rye and hairy vetch created a mulch on the soil surface which may have suppressed these weeds.

Table 3. Interaction of cover and cover management on giant foxtail (SETFA) control in 1989 and common cocklebur (XANST) control in 1990[a].

	Weed control		
	Cover		
Cover management	Rye	Hairy vetch	Soybean stubble
	% SETFA control		
No-tillage	46 b s	60 ab r	43 a s
Tilled	49 b r	49 b r	50 a r
Mowed	76 a r	80 a r	43 a s
	% XANST control		
No-tillage	71 a r	68 a r	55 ab r
Tilled	73 a rs	53 a s	83 a r
Mowed	84 a r	68 a s	41 b t

[a]Means in the same column or row followed by the same letter are not significantly different according to Fisher's Protected LSD Test ($\alpha = 0.05$). The letters a and b are used to compare cover management at the same level of cover treatment. The letters r, s, and t are used to compare cover treatments at the same level of cover management.

Table 4. Interaction of cover management and herbicide treatment on giant foxtail (SETFA) and common cocklebur (XANST) control in 1989[a].

	Weed control		
	Cover management		
Herbicide	No-tillage	Tilled	Mowed
	% SETFA control		
PRE[b]	91 a s	98 a r	90 a s
Untreated	8 b s	1 b s	43 b r
	% XANST control		
PRE	100 a r	98 a r	99 a r
Untreated	36 b s	21 b s	90 b r

[a]Means in the same column or row followed by the same letter are not significantly different according to Fisher's LSD Test ($\alpha = 0.05$). The letters a and b are used to compare herbicide treatments at the same level of cover management. The letters r and s are used to compare cover managements at the same level of herbicide treatment.

[b]Alachlor + atrazine at 2.2 + 2.2 kg ha^{-1}. Glyphosate added to the mixture in the no-tillage plots at 1.7 kg ae ha^{-1}.

Table 5. Effect of cover management and herbicide treatment on giant foxtail (SETFA) control in 1990[a].

	Weed control		
	Cover management		
Herbicide	No-tillage	Tilled	Mowed
	% SETFA control		
PRE[b]	92 a r	89 a r	90 a r
Untreated	10 b t	72 a r	42 b s

[a]Means in the same column or row followed by the same letter are not significantly different according to Fisher's LSD Test ($\alpha = 0.05$). The letters a and b are used to compare herbicide treatments at the same level of cover management. The letters r and s are used to compare cover managements at the same level of herbicide treatment.

[b]Alachlor + atrazine at 2.2 + 2.2 kg ha^{-1}. Glyphosate added to the mixture in the no-tillage plots at 1.7 kg ae ha^{-1}.

Mowed plots that did not receive a herbicide had greater weed control than no-tillage or tillage plots in 1989 (Table 4). This may be due to temperature fluctuations and a reduction in light by the mulch which may influence weed seed germination (15). Tilled plots that did not receive a herbicide treatment had greater giant foxtail control than no-tilled or mowed plots in 1990; however, mowing provided some weed control (42%) (Table 5). Variable giant foxtail germination in 1990 may have been caused by extremely wet soil conditions.

All cover management systems had good to excellent weed control, when averaged over all covers, if herbicides were used (Table 4 and 5). There was no significant interaction between cover management systems and herbicide treatments for common cocklebur control in 1990. There appeared to be no benefit from applying glyphosate at planting to control the weeds in this study. Glyphosate would not be expected to have an effect on control of these species since giant foxtail and common cocklebur usually germinate in late spring after planting corn.

No consistent differences for weed control due to cover management were observed in 1989 and 1990 (Table 2). Herbicide-treated plots had greater giant foxtail and common cockelbur control than untreated plots (Table 2).

Corn stand and height were greater in soybean stubble than in hairy vetch or rye in 1989 when averaged over all subplot and sub-subplot means (Table 2). However, soybean stubble and hairy vetch covers had greater corn stand and height than rye in 1990. Mowing reduced corn stand and height in 1989 (Table 2). Corn stand was reduced with no-till and mowed plots compared to tilled plots in 1990. This was probably caused by wet soil conditions in the spring since soil moisture is greater under mulch from a cover crop (5). Rye and hairy vetch that were mowed tended to have reduced corn stand and height both years (Table 6). This suggests that a mulch created by mowing cover crops not only affects seed germination but will also affect corn emergence and growth.

Mowed plots that did not receive a herbicide treatment had decreased corn stand both years when averaged over all covers (Table 7). This suggests that

Table 6. Interaction of cover and cover management on corn stand in 1989 and 1990[a].

	Corn stand		
	Cover		
Cover management	Rye	Hairy vetch	Soybean stubble
	plants per 22 m row		
1989			
No-tillage	87 a rs	85 a s	92 a r
Tilled	84 a s	84 a s	89 a r
Mowed	70 b s	64 b s	84 a r
1990			
No-tillage	22 b s	68 bc r	75 ab r
Tilled	65 a s	81 a r	87 a r
Mowed	54 a s	57 c s	70 b r

[a]Means in the same column or row followed by the same letter are not significantly different according to Fisher's Protected LSD Test ($\alpha = 0.05$). The letters a and b are used to compare cover managements at the same level of cover treatment. The letters r and s are used to compare cover treatments at the same level of cover management.

Table 7. Interaction of cover management and herbicide treatment on corn stand in 1989 and 1990[a].

Herbicide	Corn stand		
	Cover management		
	No-tillage	Tilled	Mowed
	—— plants per 22 m row ——		
1989			
PRE[b]	92 a r	89 a r	89 a r
Untreated	84 a r	83 a r	56 b s
1990			
PRE	58 a s	79 a r	73 a r
Untreated	52 a s	77 a r	48 b s

[a]Means in the same column or row followed by the same letter are not significantly different according to Fisher's LSD Test ($\alpha = 0.05$). The letters a and b are used to compare herbicide treatments at the same level of cover management. The letters r and s are used to compare cover managements at the same level of herbicide treatment.

[b]Alachlor + atrazine at 2.2 + 2.2 kg ha^{-1}. Glyphosate added to the mixture in the no-tillage plots at 1.7 kg ae ha^{-1}.

Table 9. Interaction of cover management and herbicide treatment on corn grain yield in 1990[a].

Herbicide	Corn yield		
	Cover management		
	No-tillage	Tilled	Mowed
	—— kg ha^{-1} ——		
PRE[b]	6190 a r	4980 a s	6650 a r
Untreated	1690 b s	2710 b r	1580 b s

[a]Means in the same column or row followed by the same letter are not significantly different according to Fisher's LSD Test ($\alpha = 0.05$). The letters a and b are used to compare herbicide treatments at the same level of cover management. The letters r and s are used to compare cover managements at the same level of herbicide treatment.

[b]Alachlor + atrazine at 2.2 + 2.2 kg ha^{-1}. Glyphosate added to the mixture in the no-tillage plots at 1.7 kg ae ha^{-1}.

mowing, when used to create a mulch, may not adequately suppress the cover crop. Previous research also indicates that hairy vetch or rye can compete with corn if not completely killed (12). However, when a herbicide was applied there were no differences among soil covers. Corn stand and height were greater in plots treated with a PRE herbicide than in untreated plots (Table 2).

Corn grain yield was reduced in rye cover plots both years (Table 2). This parallels the observed reductions in corn stand and height in mowed rye plots. Corn grain yield was lower in rye plots than soybean stubble plots in the PRE and untreated sub-subplots in 1990 (Table 8). Corn yield was also lower in the hairy vetch plots than with soybean stubble when a herbicide was not used in 1990. PRE herbicides did not prevent yield differences between covers in 1990 as they did with weed control; however, there was no significant interaction in 1989 (data not presented). This probably resulted from the decrease in corn stand and height in herbicide-treated or untreated rye plots in 1990 (data not presented).

Table 8. Interaction of cover and herbicide treatments on corn grain yield in 1990[a].

Herbicide	Corn yield		
	Cover		
	Rye	Hairy vetch	Soybean stubble
	—— kg ha^{-1} ——		
PRE[b]	2720 a s	7620 a r	7470 a r
Untreated	760 b t	2030 b s	3190 b r

[a]Means in the same column or row followed by the same letter are not significantly different according to Fisher's LSD Test ($\alpha = 0.05$). The letters a and b are used to compare herbicide treatments at the same level of cover treatment. The letters r, s, and t are used to compare cover treatments at the same level of herbicide treatment.

[b]Alachlor + atrazine at 2.2 + 2.2 kg ha^{-1}. Glyphosate added to the mixture in the no-tillage plots at 1.7 kg ae ha^{-1}.

Reduced corn height and yield in the rye plots as compared to the hairy vetch and soybean stubble plots may have been caused by reduced nitrogen availability despite high nitrogen fertilization. Corn in the rye plots was noticeably yellow by early July both years while foliage color remained green in the hairy vetch and soybean stubble plots. Nitrogen can be immobilized by rye and other small grains used as cover crops prior to planting corn (17).

Herbicide treated no-tillage plots had greater yield than tilled plots in 1990 when averaged over all covers (Tables 2 and 9). However, tilled plots had greater yield than no-tillage plots when a herbicide was not used. This may be due to greater giant foxtail control in these plots. There were no interactions for corn grain yield in 1989.

Cover crops as a mulch have been suggested as a substitute for herbicides in weed control. This study suggests that mowed rye and hairy vetch will suppress weeds; however, weed suppression with cover crops may be at the expense of crop emergence, growth, and grain yield.

Herbicides improved weed control over cover crops alone, but this was not enough to overcome yield reductions. This study also suggests that rye cover can decrease corn yields in normal and wet years, while hairy vetch did not significantly decrease yields in a wet year. Previous research has indicated that the yield decrease in corn planted into rye cover may be from reduced nitrogen availability in addition to reduced crop emergence as observed in this experiment.

There were no differences in grain yield between no-tillage and tillage. This is supported by several studies which suggest that no-tillage production systems do not decrease crop yield potential (14, 19). No-tillage has been shown to reduce soil erosion and runoff problems (11, 14). However, management of cover crops will be very important where control of soil erosion requires their use. More research is needed to fully define the role of cover crops and their effect on corn yield in reduced tillage systems.

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