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Response of Weeds to Tillage and Cover Crop Residue[1]

JOHN R. TEASDALE, C. EDWARD BESTE, and WILLIAM E. POTTS[2]

Abstract. **Total weed density increased after 1 yr of no-tillage and after 2 yr of conventional tillage in a 4-yr experiment with repeated assignment of the same treatment to the same plots. Large crabgrass, goosegrass, and carpetweed densities were higher in the no-tillage compared with the conventional-tillage treatment in at least 1 yr whereas common lambsquarters density was greater in the conventional-tillage treatment the last year of the experiment. Within the no-tillage treatment, rye or hairy vetch residue reduced total weed density an average of 78% compared to the treatment without cover crop when cover crop biomass exceeded 300 g m^{-2} and when residue covered more than 90% of the soil. Goosegrass, stinkgrass, and carpetweed densities were reduced by cover crop residue in at least 1 yr whereas large crabgrass was unaffected. Common lambsquarters density increased where rye was grown as a cover crop prior to conventional tillage. Despite differences in weed density among treatments, weed biomass was equivalent in all treatments during the last 2 yr. Nomenclature: Paraquat, 1,1′-dimethyl-4,4′-bipyridinium ion; carpetweed, *Mollugo verticillata* L. #[3] MOLVE; common lambsquarters, *Chenopodium album* L. # CHEAL; goosegrass, *Eleusine indica* (L.) Gaertn. # ELEIN; large crabgrass, *Digitaria sanguinalis* (L.) Scop. # DIGSA; stinkgrass, *Eragrostis cilianensis* (All.) E. Mosher # ERACN; corn, *Zea mays* L. 'NK-199'; hairy vetch, *Vicia villosa* Roth.; rye, *Secale cereale* L. 'Abruzzi'.**

Additional index words. *Secale cereale, Vicia villosa,* CHEAL, DIGSA, ELEIN, ERACN, MOLVE.

INTRODUCTION

Changes in tillage can have a significant effect on weed control and weed populations (20). Weed species, soil seed density, seed production, and surface residue can influence weed population dynamics under different tillage systems.

In situations with a uniform soil seed density, cultivation generally stimulates weed emergence compared to treatments without cultivation. Roberts and Dawkins (14) found greater weed emergence in cultivated compared to undisturbed plots resulting in a faster decline of the soil seed reserves in cultivated plots. Roberts and Potter (15) demonstrated that weed emergence was dependent on the timing of cultivation relative to rainfall. Ogg and Dawson (11) found that the response to tillage was species dependent; emergence of four broadleaf weed species was stimulated, three broadleaf species were unaffected, and one grass species was depressed by tillage.

Results of research investigating weed populations in crops without residual herbicides have been variable. Buhler and Daniel (3) showed that giant foxtail (*Setaria faberi* Herrm.) density was increased but velvetleaf (*Abutilon theophrasti* Medik.) density was decreased in no-tillage compared to conventional-tillage corn production. Johnson et al. (8) found no difference in foxtail (*Setaria* spp.) or common lambsquarters populations between no-tillage and conventional-tillage corn and soybean production.

In research where weeds were permitted to reseed, there have been numerous reports of shifts in weed populations in response to changes in tillage practices (7, 20). Populations of annual grass weeds have increased faster in no-tillage compared to conventional-tillage systems whereas effects on broadleaf weeds have been more variable (7, 22). However, most of these results confound the effect of tillage with herbicide performance. More research is needed on the direct effect of tillage on weed population changes over several seasons.

Cover crop residue also can influence weed populations in no-tillage cropping systems because of the proximity of the residue to the site of seed germination on the soil surface. Residue of rye and other small grains has been shown to inhibit weed emergence and growth in cropping systems (13, 17). Allelopathic compounds from rye have been isolated and identified (1, 16). Annual legume residue also has been shown to release allelochemicals that suppress germination and growth of selected species (19) but little is known about the influence of legume cover crops on weed populations in the field.

The purpose of this research was to investigate the influence of tillage and cover crop residue on weed populations in corn. The intent was to determine the direct effect of these treatments applied to the same plots over 4 yr without the confounding influence of residual herbicides.

MATERIALS AND METHODS

Research was conducted at the University of Maryland Lower Eastern Shore Research and Education Center, Salisbury, MD, from October 1985 to July 1989. The soil type was a Norfolk loamy sand (fine-loamy, siliceous, thermic Typic Paleudult) with 0.6% organic matter. Treat-

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[2]Plant Physiol., Weed Sci. Lab., U.S. Dep. Agric., Agric. Res. Serv., Beltsville, MD 20705, Assoc. Prof., Dep. Hortic., Univ. Maryland, Salisbury, MD 21801, and Statistician, Univ. Maryland/U.S. Dep. Agric. Consulting Serv., Beltsville, MD.

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

ments were assigned to 6.4- by 6.4-m plots and were arranged in a split-plot design with four replications. Whole plots were either not tilled or conventionally tilled in the spring with a moldboard plow followed by a disk. Subplots were seeded with either rye or hairy vetch, or were unseeded. The location of each plot was maintained permanently and the same treatment was applied to the same plots annually.

Abruzzi rye and hairy vetch seed were drilled at 94 and 28 kg ha^{-1}, respectively, in 17.5-cm rows in early October. Rye was killed in mid-April with paraquat applied at 0.56 kg ai ha^{-1} plus a nonionic surfactant when rye height reached approximately 45 cm. Hairy vetch was killed by paraquat at the same time as rye in 1986 but after corn planting in subsequent years. Very few winter annual weeds grew in the treatment without cover crop but these were killed with paraquat at the same time as rye.

All conventionally tilled plots were plowed during the week prior to planting. After plowing and prior to disking, 90, 39, and 74 kg ha^{-1} of N, P, and K, respectively, were broadcast over all plots. 'NK-199' sweet corn was planted in early May (late April in 1986) in 91-cm rows. Following planting, paraquat was applied at 0.56 kg ha^{-1} plus nonionic surfactant to kill any living vegetation in all plots. No residual herbicide was applied so weeds could germinate and grow without herbicidal interference after the final paraquat application. All plots were top dressed at 3 weeks after planting with 45 kg N ha^{-1} but conventional-tillage plots were not cultivated.

Cover crop biomass samples were cut and dried immediately prior to paraquat application in 1986 and at corn planting in subsequent years. Soil surface coverage by cover crop residue was estimated visually 3 to 4 weeks after planting. Weeds were counted by species in five randomly placed 0.1-m^2 frames within each plot in late June in 1986 and in early June in subsequent years. This timing was just prior to weed canopy closure which may cause self-thinning. Aboveground weed biomass samples were taken from a 4.2-m^2 area in the center of each plot in 1986 and from a 1.0-m^2 area in subsequent years at corn harvest in late July. A visual rating of species composition also was taken. After corn harvest, all plots were mowed and treated with paraquat to keep them weed free until cover crop planting in October. There was sufficient time for the dominant weed species to produce seed every year.

All data were subjected to analysis of variance using a split-split-plot model. Tillage was the whole-plot factor, cover crop was the subplot factor, and year was the sub-subplot factor. Least significant difference values were derived using the appropriate standard errors for a split-split-plot design and applied to mean comparisons where appropriate. All weed density variables were logarithmically transformed to adjust for heterogeneity of variance and nonadditivity. The transformation was of the form ln(x+c) where x is the weed density variable and c is an estimated constant (2). The constants, c, were 1.8, 3.2, 0.62, 2.1, 19, and 115 for large crabgrass, goosegrass, stinkgrass, common lambsquarters, carpetweed, and total weed density, respectively. Analysis of variance and mean comparisons were conducted on the transformed data for these variables. Means were detransformed for presentation.

RESULTS AND DISCUSSION

Weed density. Twenty weed species were encountered in sampling frames during this experiment. Large crabgrass, goosegrass, stinkgrass, carpetweed, and common lambsquarters each ranged from 8 to 56% of the total density and had a frequency of occurrence that ranged from 60 to 80% in at least 1 yr of the experiment. No other species was present in numbers that exceeded 3% of the total or a frequency that exceeded 14%. Therefore, the analysis in this paper will concentrate on the five species mentioned above.

Analysis of variance demonstrated a significant tillage by cover crop by year interaction for goosegrass, stinkgrass, and total weed density. To facilitate comparisons, means for this three-way interaction for all five species are presented.

The influence of tillage can be assessed in treatments with no cover crop (Table 1). Total weed density increased after 1 yr of reseeding in the no-tillage treatment whereas 2 yr of reseeding were required in the conventional-tillage treatment. Total weed density also was greater in the no-tillage than conventional-tillage treatments in 1987 and 1988. These results conform to the expectation that seed shed during the first year of the experiment would remain on the soil surface in the no-tillage treatment and lead to a large increase in density the following year. However, seed would be inverted by the moldboard plow during the following year in the conventional-tillage treatment and would not be introduced into the surface soil until inversion of the soil a year later. A recent model of the effect of cultivation on the vertical distribution of seed in soil predicted results similar to those presented here (6).

Species that increased in density in no-tillage versus conventional tillage were large crabgrass in 1987 and 1988, carpetweed in 1987, and goosegrass in 1989 (Table 1). There is very little known about the biology of these species which can explain this response. Large crabgrass dominated other grass species in North Carolina when no herbicides were used because of superior competitive and seed production capabilities (9). Under similar conditions of no residual herbicides in this experiment, it is not unexpected that large crabgrass was a dominant species.

Common lambsquarters density increased in conventional tillage in 1989 compared to previous years and also was greater than that in the no-tillage treatment in 1989 (Table 1). Most research with common lambsquarters also has shown that tillage stimulates emergence (10, 11, 17) but tillage had no effect in one report (8) and decreased density in another (4). Previous research does not provide a good explanation for this result. The ability of common lambsquarters to germinate at low temperatures (5, 18, 21) and at the surface of soil (18) would suggest that the absence of tillage should not greatly influence germination.

Cover crops in the no-tillage treatment had no significant influence on total weed density in 1986 and 1987 but rye residue decreased total weed density in 1988 and hairy vetch

Table 1. Influence of conventional (CT) or no (NT) tillage without cover crop applied to the same plots in four consecutive years on weed emergence 1 month after planting sweet corn[a].

Weed species	Tillage	Weed density 1986	1987	1988	1989
		no. m^{-2}			
DIGSA	CT	4 a	3 a	10 a	14 a
	NT	2 a	76 b*	51 b*	29 b
ELEIN	CT	8 a	6 a	65 b	8 a
	NT	5 a	5 a	92 b	52 b*
ERACN	CT	2 a	1 a	13 b	10 b
	NT	0 a	0 a	7 b	32 c
MOLVE	CT	16 a	19 ab	149 c	54 b
	NT	12 a	124 b*	288 c	65 b
CHEAL	CT	0 a	5 b	10 b	116 c*
	NT	0 a	2 a	4 ab	15 b
Total	CT	41 a	54 a	284 b	224 b
	NT	27 a	221 b*	612 c*	304 b

[a]Values within rows followed by the same letter are not significantly different according to the LSD (0.05) test. Values within columns and species followed by an asterisk indicate a significant difference between tillage treatments according to the LSD (0.05) test.

residue decreased total weed density in 1988 and 1989 compared to the treatment without cover crop (Table 2). Weed density reduction by cover crops in 1988 was due primarily to reductions in goosegrass and carpetweed populations. The weed density reduction by hairy vetch in 1989 was attributed to reductions in goosegrass, stinkgrass, and carpetweed populations. Large crabgrass density was not affected by cover crop residue in any year of this experiment. If reduced light levels under the residue was a factor in suppression, lack of response of large crabgrass could be explained by research which showed emergence of that species to be unaffected by reduction of light (12).

Greater influence of cover crop residue in the no-tillage treatment on weed populations during the last 2 yr of this experiment can be explained by greater cover crop biomass in those years. Regression analysis demonstrated a significant correlation between cover crop biomass and weed density reduction (Figure 1). One consequence of higher cover crop biomass is greater coverage of the soil surface by residue which can negatively affect seed germination as well as physically impede seedling emergence. Regression analysis of weed density reduction as a function of soil coverage by residue was significant and provided a better fit than obtained with cover crop biomass as the independent variable (Figure 2). This model suggests that no weed density reduction will occur until soil coverage by residue reaches 42% and that 97% coverage is required to reduce weed density by 75%. Figures 1 and 2 suggest also that there is very little difference in the capacity of rye and hairy vetch residue to suppress weeds. Further research involving more residue rates and more weed species would be needed to test this conclusion definitively.

Table 2. Influence of cover crops in the no-tillage treatment applied to the same plots in four consecutive years on weed emergence 1 month after planting sweet corn[a].

Weed species	Cover crop	Weed density 1986	1987	1988	1989
		no. m^{-2}			
DIGSA	None	2 a	76 b	51 b	29 b
	Rye	4 a	59 c	28 bc	16 ab
	Hairy vetch	3 a	58 b	68 b	30 b
ELEIN	None	5 a	5 a	92 b	52 b
	Rye	0 a	2 ab	7 b*	30 c
	Hairy vetch	4 a	2 a	22 b*	3 a*
ERACN	None	0 a	0 a	7 b	32 c
	Rye	0 a	0 a	2 b	25 c
	Hairy vetch	1 ab	0 a	2 b	2 b*
MOLVE	None	12 a	124 b	288 c	65 b
	Rye	10 a	88 b	43 b*	35 ab
	Hairy vetch	11 ab	61 c	39 bc*	5 a*
CHEAL	None	0 a	2 a	4 ab	15 b
	Rye	0 a	6 b	3 ab	25 c
	Hairy vetch	0 a	3 a	1 a	4 a
Total	None	27 a	221 b	612 c	304 b
	Rye	19 a	184 bc	96 b*	199 c
	Hairy vetch	25 a	152 b	166 b*	88 b*

[a]Values within rows followed by the same letter are not significantly different according to the LSD (0.05) test. Values within columns and species followed by an asterisk are significantly different than the treatment without cover crop according to the LSD (0.05) test.

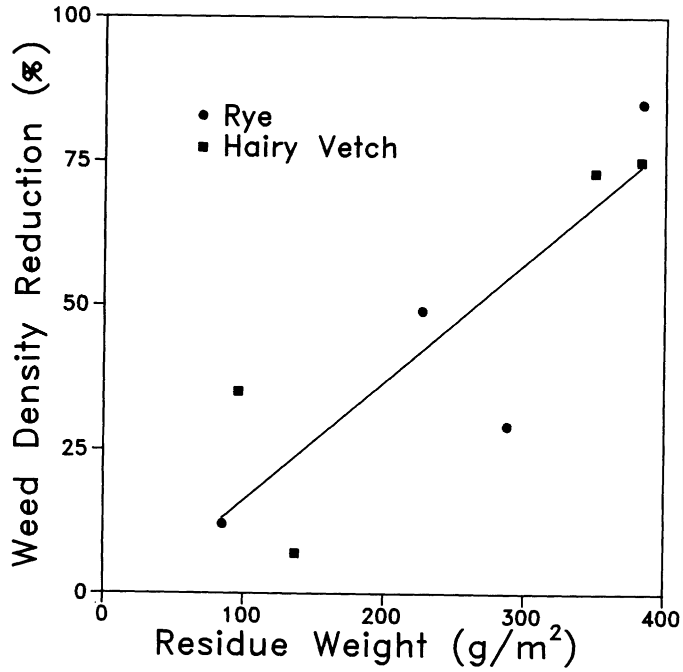

Figure 1. Regression of percentage reduction in weed density by cover crop residue in the no-tillage treatment relative to the corresponding plots without cover crop as a function of cover crop dry weight ($Y = -4.35 + 0.205X$, $R^2 = 0.75$, significant at 0.01 level). Individual points are mean values for rye or hairy vetch cover crops each year.

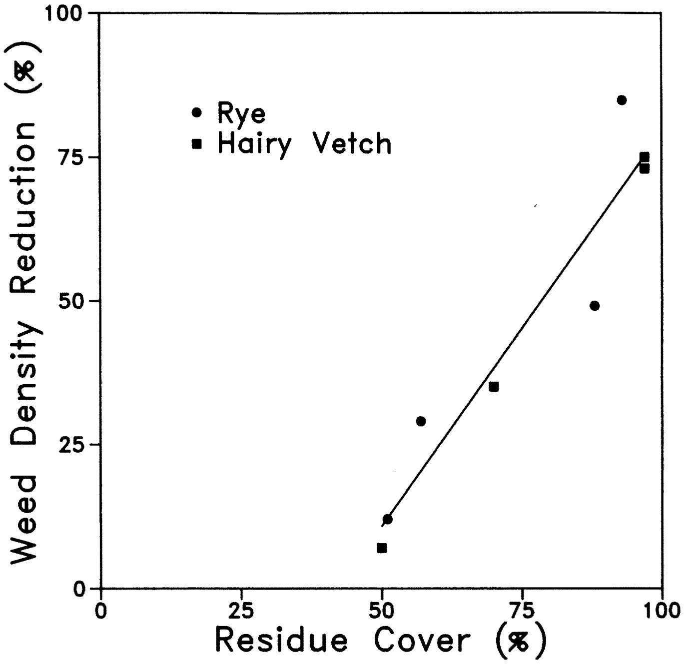

Figure 2. Regression of percentage reduction in weed density by cover crop residue in the no-tillage treatment relative to the corresponding plots without cover crop as a function of percentage of soil area covered by cover crop residue ($Y = -57.7 + 1.37X$, $R^2 = 0.91$, significant at 0.01 level). Individual points are mean values for rye or hairy vetch cover crops each year.

Table 3. Influence of cover crops in the conventional-tillage treatment applied to the same plots in four consecutive years on weed emergence 1 month after planting sweet corn[a].

Weed species	Cover crop	Weed density 1986	1987	1988	1989
		no. m^{-2}			
DIGSA	None	4 a	3 a	10 a	14 a
	Rye	3 a	13 ab	21 b	10 ab
	Hairy vetch	2 a	24 b*	3 ab	11 b
ELEIN	None	8 a	6 a	65 b	8 a
	Rye	8 a	4 a	57 b	4 a
	Hairy vetch	12 ab	2 a	58 c	13 b
ERACN	None	2 a	1 a	13 b	10 b
	Rye	1 ab	0 a	11 c	4 bc
	Hairy vetch	0 a	0 a	7 b	15 b
MOLVE	None	16 a	19 ab	149 c	54 b
	Rye	16 a	12 a	129 b	27 a
	Hairy vetch	20 a	26 ab	124 c	65 bc
CHEAL	None	0 a	5 b	10 b	116 c
	Rye	0 a	14 b	50 c*	339 d
	Hairy vetch	0 a	6 b	3 ab	37 c
Total	None	41 a	54 a	284 b	224 b
	Rye	40 a	57 a	317 b	394 b
	Hairy vetch	43 a	73 a	214 b	157 b

[a]Values within rows followed by the same letter are not significantly different according to the LSD (0.05) test. Values within columns and species followed by an asterisk are significantly different than the treatment without cover crop according to the LSD (0.05) test.

There were no significant differences in weed density between cover crop treatments within the conventional-tillage treatment in any year with two exceptions (Table 3). Large crabgrass density was greater in the hairy vetch treatment than in the treatment without cover crop in 1987. Common lambsquarters density was stimulated by rye in 1988 and this trend continued in 1989. Cover crop residue would not be expected to influence weed populations greatly in conventional tillage because residue is mixed into the soil rather than concentrated on the soil surface as in no-tillage.

Weed biomass. Analysis of variance of weed biomass and species composition showed a significant tillage by year interaction but no significant effects or interactions involving cover crop. Although cover crops decreased weed density in the no-tillage treatment, sufficient weeds became established to develop a biomass equivalent to the treatment without cover crop. Therefore, data were averaged over cover crop.

In 1986, weed dry weight was greater after conventional than after no-tillage (Table 4). This is in agreement with previous research (13, 14, 15, 17) which showed higher weed density and biomass after tillage when starting with a uniform soil seed density. Weed biomass increased after 1 yr of no-tillage but 2 yr of conventional tillage was required for a similar increase. This mirrors the rate of weed density increase shown in Table 1. By the last 2 yr of the experiment, weed density in both tillage systems had reached a level where a constant biomass was produced across all treatments despite differences in density in those years.

Grass species dominated the composition of weed vegetation in both tillage systems at the beginning of the experiment (Table 4). Carpetweed never became an important component of weed biomass, likely because of its small size and prostrate growth habit. Common lambsquarters contributed very little to the composition of weed vegetation in the first year of the experiment but increased significantly in both tillage systems over the course of the experiment. Common

Table 4. Influence of conventional (CT) or no (NT) tillage applied to the same plots in four consecutive years on weed biomass and species composition at sweet corn harvest[a].

Year	Weed dry weight CT	Weed dry weight NT	Estimated weed composition: Grass CT	Grass NT	CHEAL CT	CHEAL NT
	g m^{-2}		%			
1986	183	48	74	75	15	5
1987	167	335	69	92	29	5
1988	623	606	57	79	33	15
1989	443	411	8	53	82	38
LSD columns[b]	89		16		15	
LSD rows[c]	109		33		31	

[a]Data averaged over cover crops. Analysis of variance showed no significant effects or interactions involving cover crop.

[b]LSD (0.05) for comparison of years within tillage.

[c]LSD (0.05) for comparison of tillage within years.

lambsquarters composition increased faster in the conventional-tillage than in the no-tillage treatments and by 1989 was the dominant species in conventional-tillage plots whereas grass weeds were still the dominant species in no-tillage plots. The dramatic increase in common lambsquarters composition in both tillage systems in 1989 may be explained by cooler weather during the first 2 weeks after planting in 1989 compared to prior years. Common lambsquarters is known to germinate at cooler temperatures than most weed species (5, 18, 21) and can gain a competitive advantage from an earlier time of establishment (5).

This research shows that tillage and cover crops can influence weed population levels, the rate of population growth, and species composition. Despite the capacity of these tillage and cover crop treatments to influence weed populations, no treatment in the absence of a residual herbicide prevented weed populations from increasing to a severe level of infestation. However, cover crop residue may contribute to weed control in integrated weed management systems for no-tillage crop production.

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