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Initial Weed Densities Affect No-Tillage Weed Management with a Rye (*Secale cereale*) Cover Crop[1]

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Abstract: The objective of this research was to evaluate the influence of different initial weed densities on weed control effectiveness in no-tillage corn at two locations in North Carolina during 1994 and 1995. Different weed densities were established over a 4-year period (1989–1992) by using various weed management strategies. Resultant density levels were estimated and used to establish high and low weed density plots. Treatments applied were PRE, POST, at-planting, and an untreated control. Weed density estimates were made 37 and 57 DAP. Common lambsquarters at low densities (20 to 40 weeds/m^2) was controlled with the cover crop alone, but common lambsquarters at high densities (150 to 170 weeds/m^2) and redroot pigweed at any density were not controlled. POST herbicides reduced weed densities as well as the PRE herbicides, regardless of initial weed densities.
Nomenclature: Common lambsquarters, *Chenopodium album* L. #[3] CHEAL; redroot pigweed, *Amaranthus rebroflexus* L. #AMARE; corn, *Zea mays* L. 'Pioneer 3634'; rye, *Secale cereale* L. 'Abruzzi.
Additional index words: Allelopathy, conservation tillage, no-tillage, thresholds.
Abbreviations: DAP, days after planting; POST, postemergence; PRE, preemergence.

INTRODUCTION

No-tillage crop production is accepted as a method of reducing soil erosion, energy use, and surface water runoff. Further interest in no-tillage has arisen from conservation compliance programs. However, the increased complexity of weed control and potential increased herbicide use in no-tillage systems may be barriers to further implementation (Hinkle 1983).

Weed management in no-tillage currently relies heavily upon soil-applied preemergence (PRE) herbicides. The primary weed management system for corn in the U.S. is a PRE application of atrazine [6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine -2,4-diamine] and alachlor [2-chloro-*N*-(2, 6-diethylphenyl)-*N*-methoxymethyl)acetamide] (Worsham 1991).

Cover crops, as components of no-tillage systems, help reduce wind and water erosion, improve soil structure, fix atmospheric nitrogen, and improve soil physical and chemical characteristics (Mitchell and Teel 1977; Worsham 1990). In addition, the allelopathic effects of cover crops on weeds in crop production systems have been documented (Barnes and Putnam 1986; Putnam et al. 1983). It may be possible to supplant or reduce soil-applied herbicides with the proper selection and management of cover crops in no-tillage production systems.

A rye cover crop was used in this study because previous research demonstrated that rye effectively suppresses weeds (Barnes and Putnam 1986; Hinen and Worsham 1990; Mitchell and Teel 1977; Teasdale et al. 1991; Teasdale and Mohler 1993). It also has high biomass production potential and has winter hardiness, making it an effective choice in no-tillage soil conservation cropping systems (Worsham 1990). Rye residue can suppress early season weed growth by at least 75% (Putnam et al. 1983). Shilling et al. (1985) reported 79% early season control of broadleaf weeds with a rye much alone. Worsham found 81% redroot pigweed (*Amaranthus retroflexus* L. # AMARE) control 4 wk after planting in no-tillage corn (1990).

A cover crop alone will not provide sufficient weed control. Most grass species are not adequately controlled by a rye cover crop in no-tillage production systems (Buhler 1992; Shilling 1985; Worsham 1991). Other potential problems with weed suppression include inadequate cover crop biomass production, more difficult herbicide management, and weed species shifts (Teasdale et al. 1991; Worsham 1991). Frequently, postemergence herbicides are needed by 40 days after planting (DAP) in North Carolina (Worsham 1991).

Studies evaluating no-tillage weed control using cover crops and herbicides have not addressed how initial

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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.

weed population densities may affect subsequent weed control practices. Producers may have more confidence in no-tillage corn production and more flexibility in weed management systems they employ by knowing how initial weed densities affect weed management decisions. The objective of this study was to evaluate the influence of different initial weed densities on weed management effectiveness in a no-till corn production system.

MATERIALS AND METHODS

Experiments were conducted in 1993–1995 at the Lower Coastal Plains Research Station at Kinston, NC, and at the Tidewater Research Station at Plymouth, NC. The soil type at Kinston was a Norfolk loamy sand (fine loamy siliceous Thermic Typic Paleudults) with pH 5.6 and 1.5% organic matter. The soil type at Plymouth was a Portsmouth fine sandy loam (fine loamy/sandy mixed Thermic Typic Umbraquults) with pH 5.6 and 3.5% organic matter. The experimental design was a two by four factorial arrangement of treatments in a randomized complete block with four replications. Main plots were two weed densities, and subplots were four herbicide treatments. Main plots measured 11.9 by 15.2 m and 11.2 by 15.2 m at Kinston and Plymouth, respectively. Subplots were 5.9 by 7.6 m and 5.6 by 7.6 m at Kinston and Plymouth, respectively. Identical treatments were applied to the same plots both years at both locations.

Establishing Initial Weed Densities. Different weed densities were established on research plots at both experimental sites over a 4-year period, 1989–1992 (H. D. Coble, unpublished data). Plots were managed using preventive herbicides, remedial herbicides, mechanical cultivation, and no control (at Plymouth only) weed management programs. These plots were permanently marked each year so each treatment could be reassigned to the same physical location. New treatments were assigned to the previous experiment plots after weed densities were determined for the study described here.

1993 Field Study. Weed seedling counts were taken during the summer of 1993 to determine differences in weed densities established during 1989–1992. A rope transect was laid diagonally across main plots at 35 DAP. Ten 0.3-m^2 samples were taken randomly in each main plot along the transect. Weed seedlings were identified and counted. Following weed counts, glyphosate [*N*-phosphonomethyl) glycine] at 1.1 kg ae/ha, plus a 0.25% (v/v) nonionic surfactant were applied in 187 L/ha water at 207 kPa using 8002VS flat-fan nozzles[4] to prevent weeds from adding additional seeds to the seedbank.

1993–1995 Field Experiment. Experimental plots were moldboard plowed and disked once at the beginning of the experiment in 1993 and 1994. 'Abruzzi' rye was drilled at a rate of 170 kg/ha in September or October of 1993 and 1994 at both locations. In Kinston, plots received 340 kg/ha of 10-20-20 NPK fertilizer in September of both years. Plymouth plots received a late-winter application of 60 kg/ha N fertilizer in 1995 only.

Cover crop biomass was measured just prior to chemical desiccation in the spring of each year. The aboveground portion of the grass was clipped from 12 randomly selected 0.6-m^2 sections of the 7.6-m alleys, dried at 60 C for 48 h, and weighed. Both years, glyphosate at 1.1 kg/ha, plus a 0.25% (v/v) nonionic surfactant, were applied in 187 L/ha water at 207 kPa using 8002VS flat-fan nozzles 2 wk prior to corn planting.

In early to mid-April of both years 'Pioneer 3163' corn was planted in 76.2-cm rows at 64,000 seeds/ha using a no-till planter. NPK fertilizer (10-34-0) at 107 L/ha and 2.2 kg ai/ha granular chloropyrifos (*O,O*-diethyl *O*-(3,5,6-trichloro-2-pyridinyl) phosphorothioate) were applied in-furrow at planting.

Subplot weed management treatments were established immediately after corn planting. The four weed management programs in 1994 were: (1) a preventive PRE treatment of 1.4 kg ai/ha of atrazine, plus 2.2 kg ai/ha of alachlor; (2) a postemergence (POST) treatment of 0.27 kg ai/ha of dicamba (3, 6-dichloro-2-methoxybenzoic acid) plus 0.25% (v/v) nonionic surfactant applied POST 47 DAP; (3) 0.4 kg/ha of glyphosate plus 0.25% (v/v) nonionic surfactant applied at planting at Plymouth only; and (4) an untreated control without supplemental herbicides.

Changes in herbicide applications were made in both years due to conditions encountered in the field. In 1994, no at-planting glyphosate application was made because weeds had not emerged due to dry conditions. In 1995, changes to the weed management treatments were as follows: (1) at Plymouth, preventive herbicide rates were increased to 1.7 kg/ha of atrazine plus 2.8 kg/ha of alachlor due to the negative effect of high soil organic matter on herbicide efficacy, and (2) the POST treatment was changed at both locations to 0.3 kg/ha of dicamba plus 0.04 kg ai/ha of nicosulfuron 2-[[[[4, 6-dimethoxy-2-pyrimidinyl]amino]carbonyl]amino]sulfonyl]-*N*, *N*-di-

[4] Teejet spray nozzles, Spraying Systems Co., P.O. Box 7900, Wheaton, IL 60189.

methyl-3-pyridinecarboxamide plus 0.25% (v/v) nonionic surfactant applied POST 37 DAP.

All herbicides were broadcast-applied by a CO_2-pressurized backpack sprayer. Preemergence and at-planting herbicides were applied in 187 L/ha water at 207 kPa through 8002VS flat-fan nozzles. POST applications were delivered in 187 L/ha water at 207 kPa through 11002VK flat-fan nozzles to the lower 15 cm of 60- to 90-cm tall corn.

Five permanent 0.6-m^2 sampling plots were randomly established in each subplot 3 wk after planting each year. The center of each plot was sampled by placing a 0.6-m^2 sampling square over the row, identifying weeds, and counting. The area was permanently flagged to ensure that the same location was sampled each time.

Weed counts were taken 37, 57, 72, and 84 DAP at both locations in 1994. The number of sampling dates was halved in 1995, because statistical analysis of 1994 data showed that there was no difference between the second weed count and the final two weed counts. Consequently, weed counts in 1995 were taken 37 and 57 DAP at both locations.

Following the final weed count 84 DAP in 1994, weeds were removed from all plots to prevent seeding and to maintain relative weed population differences. A sickle-bar mower with a 35-cm mowing head was used to mow weeds between rows. Approximately 2 wk later, 0.5 kg/ha glyphosate plus 0.25% (v/v) nonionic surfactant in 187 L/ha water at 207 kPa through 8002VS flat-fan nozzles was directed at the lower 15 cm of the mature corn plants to control additional weeds.

Establishing Initial Weed Densities. Twenty weed species were identified during initial weed counts in 1993 at both locations (Zasada 1995). Differences in weed densities were observed as a result of the weed management programs employed during 1989–1992.

The PRE and POST herbicide treatments during 1989–1992 resulted in weed densities that could not be statistically separated, so they were grouped to comprise the low initial weed density category at both locations. High weed densities resulted from the mechanical cultivation treatment at Kinston and the untreated control at Plymouth. Data were used to establish density category (low or high) ranges (Table 1).

Redroot pigweed and common lambsquarters accounted for 85% of the total weeds present at both locations. At Plymouth, several grass species were found in addition to broadleaf weeds but not consistently enough for a separate analysis. Data for all weeds, grass weeds, and broadleaf weeds were analyzed separately but provided no additional insight when compared to redroot pigweed and common lambsquarters results. All results presented will be common lambsquarters and redroot pigweed data.

Table 1. Weed density ranges used to establish initial low and high weed densities at Kinston and Plymouth in 1993.

	Weed density			
	Kinston		Plymouth	
Weed	Low	High	Low	High
	No./m^2			
Redroot pigweed	10–54	86–128	22–60	150–188
Common lambsquarters	10–42	172–204	22–44	130–152
Total broadleaf weeds	21–105	268–332	42–148	344–450
Total grass weeds	—	—	54–98	214–258
Total weeds	75–113	344–382	96–156	548–608

All measurement data were different between years and locations so results are presented by location and year. The PRE treatment provided either complete or near complete weed control at both locations for either initial weed density. Discussion of results will concentrate on the POST, at-planting, and untreated control treatments.

Statistical Analysis. Analysis of variance was performed on the weed counts using SAS[5] General Linear Models (GLM) procedures to determine significant differences between means across and within years. Means for main effects and interactions were separated by a protected LSD test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Rye Biomass. Rye aboveground biomass was used as an indicator of cover crop performance. The average biomass production of the cover crop at Kinston was 720 and 750 g/m^2 in 1994 and 1995, respectively, and at Plymouth 450 and 580 g/m^2 in 1994 and 1995, respectively. These values are within the normal production range reported in previous rye cover crop research (Teasdale et al. 1991; Yenish 1994).

Weed Density Studies. There were no differences in common lambsquarters density at either 37 or 57 DAP among management systems at low initial density at Kinston in either year (Table 2). The rye cover crop alone provided good control. The at-planting and untreated control treatments were not different and were significantly less than the POST treatment for common lambsquarters 57 DAP at high densities both years. No

[5] General Linear Models Procedures of SAS (Statistical Analysis System), SAS Institute, Cary, NC 27512.

Table 2. The effect of a weed management system and initial weed density on common lambsquarters and redroot pigweed density at Kinston in 1994 and 1995.[a]

		Common lambsquarters				Redroot pigweed			
		37 DAP[b]		57 DAP		37 DAP		57 DAP	
Weed management system	Year	Low	High	Low	High	Low	High	Low	High
		No./m²							
PRE[c]	1994	0 NS	0 a	0 NS	0 a	0 NS	0 a	0 a	0 a
POST[c]		3 NS	35 b	0 NS	1 a	3 NS	15 b	1 a	3 a
At-planting[c]		1 NS	34 b	1 NS	42 b	3 NS	17 b	3 b	19 b
Untreated control		1 NS	37 b	1 NS	40 b	2 NS	16 b	4 b	15 b
PRE[c]	1995	0 NS	0 a	0 NS	0 a	0 a	0 a	0 a	0 a
POST[c]		1 NS	10 b	0 NS	0 a	13 b	13 b	0 a	0 a
At-planting		1 NS	7 b	0 NS	10 b	11 b	11 b	8 b	19 b
Untreated control		0 NS	11 b	1 NS	15 b	17 c	8 b	17 b	23 b

[a] Means within a column within a year followed by the same letter are not significantly different ($P \leq 0.05$) according to a protected LSD test. NS, nonsignificant.

[b] DAP, days after planting.

[c] PRE = 1.4 kg/ha atrazine plus 2.2 kg/ha alachlor. POST = 0.3 kg/ha dicamba applied 40 DAP. At-planting = not applied in 1994.

differences were found among treatments for redroot pigweed at low initial densities at 37 DAP in 1994. In 1995, the POST and at-planting treatments had fewer redroot pigweed plants than the untreated control at 37 DAP. By 57 DAP, the POST treatments were better than the at-planting or untreated control both years. POST herbicides provided equal control, while at-planting and the untreated control gave significantly worse control at high initial densities each year. The at-planting treatment was no better than untreated control at either initial density levels or weed species in 1995.

No differences were found among treatments for either species at Plymouth both years at 37 DAP and low initial weed densities (Table 3). Statistical differences were found among treatments for common lambsquarters at 37 DAP at high initial weed densities in both years, but at this result, they have little practical implications. POST treatments were more effective than at-planting and untreated control treatments by 57 DAP each year. No difference was found among treatments both years for redroot pigweed at 37 DAP. POST treatments provided better results than the at-planting or untreated control at 57 DAP either year.

Several different strategies were tested as alternatives to automatic PRE herbicide use in no-till corn. An at-planting glyphosate application at 1.1 kg ae/ha was evaluated as a means of controlling emerged weeds early and utilizing corn's relatively inexpensive herbicide, which could reduce production costs, making corn a more profitable crop in North Carolina. This treatment rarely reduced weed populations compared to the untreated control due to weed emergence after application and cannot be considered a viable alternative, even at low weed densities.

Table 3. The effect of a weed management system and initial weed density on common lambsquarters and redroot pigweed density at Plymouth in 1994 and 1995.[a]

		Common lambsquarters				Redroot pigweed			
		37 DAP[b]		57 DAP		37 DAP		57 DAP	
Weed management system	Year	Low	High	Low	High	Low	High	Low	High
		No./m²							
PRE[c]	1994	0 NS	0 a	0 NS	0 a	0 NS	0 a	0 NS	0 a
POST[c]		2 NS	17 c	0 NS	2 a	1 NS	2 b	0 NS	0 a
At-planting[c]		2 NS	11 b	3 NS	21 b	1 NS	1 b	1 NS	2 b
Untreated control		2 NS	17 b	1 NS	30 b	0 NS	3 b	0 NS	3 b
PRE[c]	1995	0 NS	0 a	0 a	0 a	0 NS	0 a	0 a	0 a
POST[c]		13 NS	99 c	0 a	0 a	0 NS	7 b	7 b	0 a
At-planting		12 NS	92 bc	14 b	93 b	1 NS	4 ab	2 a	7 c
Untreated control		8 NS	75 b	8 b	77 b	1 NS	3 ab	1 a	4 b

[a] Means within a column within a year followed by the same letter are not significantly different ($P \leq 0.05$) according to a protected LSD test. NS, nonsignificant.

[b] DAP, days after planting.

[c] PRE = 1.4 kg/ha atrazine plus 2.2 kg/ha alachlor. POST = 0.3 kg/ha dicamba applied 40 DAP. At-planting = not applied in 1994.

A rye cover crop without additional herbicides performed adequately to reduce common lambsquarters populations at low initial densities but not at high densities. Low densities of redroot pigweed were also reduced early in the season, but reductions were not consistent and not sustained during the growing season.

A POST herbicide application consistently reduced weed populations to levels found in the PRE treatment regardless of the initial weed populations. The availability of selective, highly efficacious herbicides allows POST control efforts to be as effective as PRE measures and should be considered a workable option.

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