Screening Cover Crops for Use in Conservation Tillage Systems for Vegetables Following Spring Plowing

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Abstract. Several prospective cover crops were sown into 1-m² monoculture plots on 9 Mar. 1987 and 10 Mar. 1988 at Bixby, Okla., and on 14 Mar. 1988 at Lane, Okla., after sites were plowed and fitted. Densities and dry weights of cover crops and weeds were determined in late April or early May of both years. Plots also were evaluated for degree of kill by glyphosate in 1988. Fourteen cover crops were screened at Bixby in 1987. Kentucky bluegrass (*Poa pratensis* L.) and three fescues (*Festuca rubra* L., *Festuca rubra* L. var. *commutata* Gaud.-Beaup., and *Festuca elatior* L.) were eliminated from further consideration due to inadequate cover density and inability to suppress weeds. Screenings of the 10 remaining covers were conducted at both locations in 1988. Annual ryegrass (*Lolium multiflorum* L.) and three small grains [rye (*Secale cereale* L.), barley (*Hordeum vulgare* L.), and wheat (*Triticum aestivum* L.)] were the most promising cover crops with respect to cover density, competitiveness against weeds, and degree of kill by glyphosate. Crimson clover (*Trifolium incarnatum* L.) and hairy vetch (*Vicia villosa* Roth) were the most promising legumes, but they generally were less satisfactory than the grassy covers in all tested aspects. A single application of glyphosate was ineffective in killing hairy vetch at both locations. Chemical name used: N-(phosphonomethyl)glycine (glyphosate).

Interest in conservation tillage for crop production has developed in response to concerns over soil erosion. The principles and benefits of conservation tillage have been reviewed (Allmaras and Dowdy, 1985; Phillips et al., 1980; Unger and McCalla, 1980). Many experiments have been conducted on conservation tillage for field crops, and an extensive literature base has been formed. Fewer studies have been conducted on conservation tillage for vegetable crops. A review of these studies led to two conclusions. First, reduced tillage was more promising than no tillage as a strategy for production of several vegetables (Beste, 1983; Doss et al., 1981; Knavel and Herron, 1981; Robinson, 1985). Second, "living mulches" (Hughes and Sweet, 1979) usually

have proven to be excessively competitive with interplanted vegetable crops (Altieri et al., 1985; Nicholson and Wien, 1983).

The present study marked the beginning of an effort to develop a conservation tillage system for warm-season vegetable production that did not exclude some tillage and that used killed cover crops. The objective of the present study was to identify one or more cover crops that would establish quickly following spring plowing and produce a completely killed, dense, weed-free ground cover into which warm-season vegetables could be planted in mid-spring. Monoculture screenings of several prospective cover crops were conducted with respect to adaptation, density, biomass production, competitiveness with weeds, and degree of suppression obtained from a single glyphosate application.

Studies were conducted in 1987 and 1988 at the Vegetable Research Station, Bixby, Okla., on a Severe very fine sandy loam [coarse-silty, mixed (calcareous), thermic Typic Udifluvents]. A second experimental site in 1988 was the Wes Watkins Agricultural Research and Extension Center, Lane, Okla. The soil type at Lane was a Bernow fine sandy loam (fine-loamy, siliceous, thermic Glossic Paleudalf). The experimental design at both locations was a randomized complete block with four replications.

Initial soil preparation at both sites consisted of plowing and harrowing. A broadcast, preplant-incorporated application of fertilizer was made at Bixby in both years; fertilizer rates were 58N-26P-48K (kg·ha⁻¹) in 1987 and 60N-27P-50K (kg·ha⁻¹) in 1988, respectively. No supplemental fertilization was used at Lane, and no supplemental irrigation was used at either location. Rainfall during the period between seeding and plot sampling totaled 80 mm at Bixby in 1987, 90 mm at Bixby in 1988, and 100 mm at Lane in 1988.

The cover crops were seeded by hand into 1-m² plots using normal pasture rates (Martin et al., 1976) (Table 1). Germination tests were conducted before planting each year and the seeding rates adjusted accordingly. Seeds were weighed for each plot to ensure correct planting rates, broadcast as uniformly as possible, and incorporated with a light bow-raking, with the exception of the large-seeded legumes (hairy vetch and Austrian winter pea). These two crops were sown in three shallow furrows per plot, spaced at 30 cm between furrows. All legume seeds were inoculated with appropriate *Rhizobia*. Control plots also were bow-raked. Fourteen covers were screened at Bixby in 1987 (Table 1). Kentucky bluegrass and the three fescues were eliminated following this initial study, and the remaining 10 covers were screened at both locations in 1988. Sowing dates were 9 Mar. 1987 and 10 Mar. 1988 at Bixby and 14 Mar. 1988 at Lane.

The plots were evaluated on 7 May 1987 and 25 Apr. 1988 at Bixby and on 2 May 1988 at Lane. The densities of the cover crop and weed populations were determined using the rope-knot method of Sloneker and Mol-

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Table 1. Cover crops and seeding rates used in monoculture screenings.

Common name	Scientific name	Seeding rate (g·m ⁻²)
Barley	<i>Hordeum vulgare</i> L.	9.4
Oats	<i>Avena sativa</i> L.	9.9
Rye	<i>Secale cereale</i> L.	7.8
Wheat	<i>Triticum aestivum</i> L.	8.4
Annual ryegrass	<i>Lolium multiflorum</i> L.	3.1
Chewing's fescue	<i>Festuca rubra</i> L. var. <i>commutata</i> Gaud.-Beaup.	3.1
Red fescue	<i>Festuca rubra</i> L.	3.1
Tall fescue	<i>Festuca elatior</i> L.	3.1
Kentucky bluegrass	<i>Poa pratensis</i> L.	2.2
Crimson clover	<i>Trifolium incarnatum</i> L.	2.2
Red clover	<i>Trifolium pratense</i> L.	1.1
White clover	<i>Trifolium repens</i> L.	0.7
Austrian winter pea	<i>Pisum sativum arvense</i> (L.) Poir	6.7
Hairy vetch	<i>Vicia villosa</i> Roth	3.4

Table 2. Characteristics of cover crops grown in monoculture, 1-m² plots at Bixby, Okla., 1987.

Cover crop	Portion (%) of ground covered by:		Bare soil (%)	Dry wt weeds : dry wt cover	Cover crop ht (cm)
	Cover crop	Weeds			
Control	---	44 a	56 a	---	11 ^y d
Barley	83 b ^z	1 f	16 de	<0.1 b	28 a
Oats	73 c	5 def	22 bcd	<0.1 b	28 a
Rye	93 a	2 f	5 f	<0.1 b	30 a
Wheat	74 c	7 def	19 cde	<0.1 b	20 bc
Annual ryegrass	85 b	4 ef	10 ef	<0.1 b	18 c
Chewing's fescue	37 f	35 ab	28 bc	3.3 a	4 g
Red fescue	51 e	22 bc	27 bcd	2.7 a	5 fg
Tall fescue	49 e	29 ab	22 bcd	0.8 b	8 e
Kentucky bluegrass	28 g	41 a	31 b	4.3 a	3 g
Crimson clover	72 c	11 cde	17 cde	0.1 b	12 d
Red clover	53 de	19 bc	28 bc	0.4 b	14 d
White clover	58 de	24 bc	18 cde	0.8 b	7 ef
Austrian winter pea	62 d	15 cd	23 bcd	0.1 b	21 b
Hairy vetch	83 b	13 cde	4 f	0.1 b	13 d

^yMean separation in columns by Waller-Duncan *t* test, K ratio = 100.

^zMean height of weeds in control plots, for comparison with cover crop heights.

Table 3. Characteristics of cover crops grown in monoculture, 1-m² plots at Bixby, Okla., 1988.

Cover crop	Portion (%) of ground covered by:		Bare soil (%)	Dry wt weeds : dry wt cover	Cover crop ht (cm)	Kill by glyphosate (%)
	Cover crop	Weeds				
Control	---	33 a	67 a	---	3 ^y ef	96 a
Barley	73 ab ^z	8 e	19 ef	<0.1 c	9 b	100 a
Oats	43 ef	12 cde	45 b	<0.1 c	6 d	100 a
Rye	65 bc	8 e	27 de	<0.1 c	10 ab	100 a
Wheat	61 bcd	12 cde	27 de	<0.1 c	7 cd	100 a
Annual ryegrass	78 a	10 de	12 f	<0.1 c	11 a	98 a
Crimson clover	62 bc	12 cde	26 de	<0.1 c	5 d	71 b
Red clover	53 cde	21 bc	26 de	0.2 bc	6 d	63 bc
White clover	39 f	20 bcd	41 bc	0.4 a	4 e	56 c
Austrian winter pea	49 def	16 bcde	35 cd	0.3 ab	8 c	61 bc
Hairy vetch	46 ef	23 ab	31 d	0.2 bc	2 f	9 d

^yMean separation in columns by Waller-Duncan *t* test, K ratio = 100.

^zMean height of weeds in control plots, for comparison with cover crop heights.

Table 4. Characteristics of cover crops grown in monoculture, 1-m² plots at Lane, Okla., 1988.

Cover crop	Portion (%) of ground covered by:		Bare soil (%)	Dry wt weeds : dry wt cover	Cover crop ht (cm)	Kill by glyphosate (%)
	Cover crop	Weeds				
Control	---	54 a	46 a	---	7 ^y bc	64 a
Barley	46 c ^z	30 cd	24 bcd	0.7 c	8 b	71 a
Oats	60 b	17 de	23 cd	0.3 c	14 a	52 ab
Rye	83 a	7 e	10 e	0.1 c	13 a	68 a
Wheat	47 c	31 cd	22 cde	0.2 c	7 bc	69 a
Annual ryegrass	70 b	17 de	13 de	0.1 c	10 ab	35 bc
Crimson clover	18 de	47 abc	35 abc	4.6 c	3 cd	21 cd
Red clover	14 e	49 ab	37 abc	13.1 b	4 cd	15 cd
White clover	11 e	53 a	36 abc	23.2 a	2 d	9 de
Austrian winter pea	10 e	50 ab	40 a	13.3 b	6 bcd	48 ab
Hairy vetch	25 d	36 bc	39 ab	2.4 c	3 cd	1 e

^yMean separation in columns by Waller-Duncan *t* test, K ratio = 100.

^zMean height of weeds in control plots, for comparison with cover crop heights.

denhauer (1977) as adapted by Nicholson and Wien (1983). Cover crop heights also were measured (three readings per plot, which were averaged). Following these evaluations, plots were sampled using a 50 × 50-cm square. All plants within the boundaries of the square were cut by hand at soil level, separated into weeds and cover crops, dried at 55C for at least 3 days, and weighed. Sampling oc-

curred on 14 May 1987 and 26 Apr. 1988 at Bixby and on 5 May 1988 at Lane. Dry-weight comparisons were made through ratios of weed dry weights to cover crop dry weights. Thus, any plot producing a ratio greater than one contained more weed biomass than cover crop biomass.

Glyphosate was applied to the plots after sampling in 1988. The rate at Bixby was 1.7

kg·ha⁻¹, with a water carrier, a spray volume of 262 liters·ha⁻¹, and no adjuvants. The rate at Lane was higher (2.2 kg·ha⁻¹) due to greater weed pressure. The Lane treatment involved a water carrier, a spray volume of 98 liters·ha⁻¹ and a spreader added at 0.25% v/v (X-77; Valent USA, Walnut Creek, Calif.). There was no rainfall within 24 h of application at either site. Visual estimations of percent kill of the cover crops were made 18 and 24 days after treatment at Bixby and Lane, respectively, by two persons working independently and were averaged. Glyphosate generally killed most of the weeds present in the plots, especially at Bixby.

Data were evaluated with an analysis of variance. Mean separations were performed using the Waller-Duncan *t* test with a K ratio equal to 100.

Bixby, 1987. The greatest percentage of ground cover was produced by rye (Table 2). Relatively high cover crop densities also were produced by barley, wheat, oats, annual ryegrass, hairy vetch, and crimson clover (Table 2). The four small grains and annual ryegrass also provided a high degree of weed suppression, with three of the four turfgrasses (Chewing's fescue, tall fescue, and Kentucky bluegrass) not significantly different from the weedy control. All covers reduced the amount of bare soil compared to the weedy control, with only 5% and 4% bare soil remaining in the rye and hairy vetch plots, respectively (Table 2). Kentucky bluegrass, Chewing's fescue, and red fescue all produced weed : cover dry weight ratios >1.0, while the four small grains and annual ryegrass all produced ratios <0.1. Rye, oats, and barley were taller than the other crops, with the four turfgrasses and white clover producing the least amount of vertical growth (Table 2). At the conclusion of this study, the four turfgrasses were eliminated from further consideration due to poor establishment of ground cover and inadequate competition against weeds.

Bixby, 1988. The general tendencies observed in 1987 were reinforced by the screening of the remaining 10 crops in 1988. Grassy covers tended to perform better than leguminous crops. Annual ryegrass produced a higher percentage of ground cover than any other crop, except barley (Table 3). However, due to bird damage, the percentages of ground cover resulting from growth of the small grains were somewhat lower than those observed in 1988, with oats suffering the greatest reduction. Barley and rye plots contained only 8% ground cover due to weeds, but did not differ significantly in weed suppression from oats, wheat, annual ryegrass, crimson clover, and Austrian winter pea. Hairy vetch was not significantly different from the weedy control in weed density, in contrast to the result from 1987. All covers reduced the amount of bare soil compared to the weedy control, as in 1987, with annual ryegrass plots containing less exposed soil than plots of any other cover, except barley (Table 3). All crops produced weed : cover dry weight ratios <1.0, with

six of the 10 crops having ratios <0.1. The tallest crops were annual ryegrass, rye, and barley, while white clover and hairy vetch were the shortest crops screened. The five grassy crops exhibited at least 98% kill by glyphosate, in general agreement with the findings of Weston (1990). The legumes were intermediate in the degree to which they were killed, except for hairy vetch, which was tolerant to the herbicide (Table 3).

Lane, 1988. There was some unexplained difficulty with legume stand establishment at Lane. Consequently, the four small grains and annual ryegrass produced the greatest percentages of ground cover (Table 4). Rye was particularly suppressive to weed establishment (Table 4). Among the legumes, only hairy vetch gave a significant reduction in ground cover due to weeds, compared to the weedy control and in contrast to the finding at Bixby in 1988. No legume crop significantly reduced the amount of bare soil compared to the weedy control (Table 4). Weed pressure was high, and five of the cover crops produced weed : cover dry weight ratios >1.0. However, only three legumes (white clover, Austrian winter pea, and red clover) were significantly different from the remaining seven crops. Oats and rye were the only crops to exceed the mean height of the weeds. Glyphosate was less effective in killing the cover crops at Lane than at Bixby in 1988, despite the higher rate used at Lane. The grassy covers again proved to be easiest to kill, and hairy vetch again exhibited tolerance to the herbicide (Table 4).

Overall, rye, annual ryegrass, barley, and wheat emerged as the most promising cover crops with respect to cover density, competitive ability against weeds, and degree of kill obtained from a single application of glyphosate. These results generally agree with those of Moschler et al. (1967), except that we did not observe herbicide tolerance with barley (Moschler et al. did not use glyphosate). All four of the most promising cover crops were grasses. Weston (1990) reported that rye and wheat were superior cover crops for vegetable no-tillage systems compared to some of the same species that were screened in the present study, including tall fescue, creeping red fescue, and white clover. Crimson clover and hairy vetch were the best legumes in the present study, in agreement with the findings of Hoyt and Hargrove (1986). However, the high degree of tolerance to glyphosate exhibited by hairy vetch indicates that an alternative, effective herbicide must be found before this cover crop can be used in a killed-cover conservation tillage system.

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