COVER CROP SCREENING FOR CONSERVATION TILLAGE AND A PRELIMINARY REPORT ON RELAY INTERCROPPING FOR VEGETABLE PRODUCTION IN OKLAHOMA

By

WENDY ANN NELSON

Bachelor of Science in Agriculture

Oklahoma State University

Stillwater, Oklahoma

1987

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 1990

COVER CROP SCREENING FOR CONSERVATION
TILLAGE AND A PRELIMINARY REPORT
ON RELAY INTERCROPPING FOR
VEGETABLE PRODUCTION
IN OKLAHOMA

Thesis Approved:

Brian A. Kahn
Thesis Advisor

B. Warren Roberts

Jewell Crabtree

James E. Motes

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGEMENTS

The simple etchings of pen on papper have been known to ellicit a multitude of feelings within those who read them. If meticulously assembled, the written word can move people to hysterical laughter, teaful outpourings or fiery rage. However, in the oppinion of this untrained author the most difficult feeling or emotion to effectively and convincingly convey is that of appreciation or grattitude. Although the motivational thoughts behind the expression of one's grattitude may be just as intense or passionate as any other emotion, often the words through which these feelings are communicated are perceived as a mundane rhetoric of cliches devoid of feeling. Thus, as you take into consideration the sentiments of acknowlegement communicated herein let the limitations of the written word be removed to reveal the sincerity and intensity of the thoughts and feelings which these mere type-written symbols must represent.

In an institution for higher learning where professors are constantly confronted with deadlines and hectic schedules, it is rare to find an individual who is willing to devote numerous hours to the advisory duties to which they are assigned. However, being one of the fortunate few, I obtained such an advisor for not only my undergraduate but also my graduate years at Oklahoma State. It is to this man, Dr. Brian Kahn, that I owe a great deal of praise and appreciation. His patience, encouragement and guidance throughout the course of my college career are largely responsible for my personal academic achievements.

A further expression of gratitude must be made to the members of my graduate committee, Dr. R. Jewell Crabtree, Dr. B. Warren Roberts, and Dr. James E. Motes. Gentlemen your suggestions, comments and critiques proved invaluable during the preparation of this manuscript. Your concerns and cooperation will always be greatly appreciated.

Although a great wealth of knowlege can be obtained from textbooks, there is a vast amount of information that one must experience in order for it to be fully comprehended. With this aspect of learning in mind, I will forever be indebted to Bruce Bostian. As Superintendent of the Vegetable Research Station at Bixby, he was instrumental in my instruction and realization of the more practical applications of horticultural training.

To my fellow graduate students and classmates, I wish to extend a heart-felt thank you for the kindness and comradery you have shown me during the past years. The assistance furnished by Brends Simons and Kim Walls also must not go unrecognized. Their countless consultations could easily be associated with the successful conversion of this manuscript into final form.

Finally, to my parents, Brad and Linda Nelson, sister, Amanda, grandparents, great-grandparents and loyal friends, Dwayne and Dena, who have all graciously given their unconditional love, encouragement and devotion, I wish to convey my deepest sentiments of appreciation. Without you in my life, all achievements would simply be meaningless tasks.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

CHAPTER I

INTRODUCTION

Public awareness and recognition of environmental concerns is increasing. This realignment of public concern has resulted in an increasing desire to conserve natural resources. As part of this conservation movement, interest in reduced tillage techniques has increased.

Although conservation tillage is not new, it has only recently been used by vegetable producers. In contrast, numerous experimenters have investigated the adaptation and integration of reduced-till systems into field crop production. As the profitability of field crop production decreases many producers are converting to vegetable crop production. This conversion has resulted in a need for research on reduced-till methods of vegetable production.

Reduced-till research has been conducted in other areas of the country and has yielded mixed results. Research identifying tillage components best suited for Oklahoma has yet to be reported. Research on reduced-till programs suited for vegetable production in Oklahoma was initiated by the two studies described here. The studies were conducted with the following objectives:

1. Identifying one or more cover crops which 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.

2. Determine whether relay intercropping can maintain pepper yield and quality while providing cover crop residues into which fall broccoli can be transplanted following strip-tillage.

CHAPTER II

LITERATURE REVIEW

Putnam (1972) reported that a no-till production system involving asparagus (<u>Asparagus officinalis</u> L.) grown from crowns gave a twenty-seven percent increase in yield relative to conventional tillage during the first three harvest seasons.

In 1973 Beste used either a conventional seedbed or an untilled seedbed of killed rye sod to evaluate herbicides for three vegetable crops [cucumbers (<u>Cucumis sativus</u> L.), lima beans (<u>Phaseolus lunatus</u> L.), and tomatoes (<u>Lycopersicon esculentum</u> Mill.)]. For all three vegetable crops, acceptable weed control in the no-till plots was achieved with several standard herbicide treatments. When weed control was adequate, tomato and lima bean yields were shown to be similar in both tilled and no-till plots. However, cucumber yields were less in no-till than in tilled plots.

Smith et al. (1973), using an experimental grassland renovator, seeded tomatoes and cucumbers into a tall fescue sod which had been killed with a herbicide. Both crops achieved good emergence and acceptable stands.

Comparisons between no-till and conventional tillage techniques for several vegetable crops were made by Knavel et al. (1977) on a silt loam soil in Kentucky. In the no-till system, general reductions occurred in the yields of transplanted tomatoes and peppers (Capsicum annuum L.). However, the authors attributed these losses primarily to the increased weed reinfestation of the no-till plots when contrasted to the conventionally tilled plots. When stand establishment was comparable, both tillage systems produced similar yields of direct-seeded cucumbers in two out of three years. Yields of no-till plots were lower than conventionally tilled plots if poor stand establishment was experienced. All yields obtained from no-till sweet corn (Zea mays L.) were equal to or greater than yields from conventional-till plots.

Orzolek and Carroll (1978) found no significant differences in yield between carrots (Daucus carota L.) planted into a rye mulch, soybean stubble or conventionally tilled plots. Carrots grown in soybean stubble had more secondary root growth than carrots grown in the other two treatments.

Snap beans (Phaseolus vulgaris L.) and lima beans were grown by Mullins et al. (1980) in a three year tillage study in Tennessee. The tillage treatments included two no-till systems, two reduced-till systems and a conventional till system. Mean snap bean yield was not affected by tillage system. However, mean lima bean yield was highest with the conventional tillage treatment.

Using a winter cover crop of rye in Alabama, Doss et al. (1981) compared the effects of complete tillage, strip tillage and no tillage on tomato yields. The production of marketable tomatoes tended to decline as the degree of tillage declined. Plots without rye also tended to have higher marketable yields than plots with rye. The authors believed the detrimental effects of rye plots could have been reduced or eliminated if the rye cover had been killed earlier, thus allowing rainfall to replace the rye-induced soil moisture losses.

Knavel and Herron (1981) compared conventional tillage production of spring cabbage (Brassica oleracea L. Capitata Group) to no-till production. They concluded that spring cabbage production in a no-till system was not economically feasible under their experimental conditions (a silt loam soil in Kentucky).

Herbicide and tillage influences on sweet corn double-cropped after peas (Pisum sativum L.) were studied by Ndon and Harvey (1981). They concluded that with regard to sweet corn population and yield, conventional tillage was better than minimum tillage. Increased plowing increased the rate at which weeds germinated and grew in the conventionally tilled plots.

Wilson et al. (1982) investigated the effects various cover crops had on subsequent arable crops grown in a strip-tilled system. Both grassy and leguminous cover types were tested. Grassy covers were more difficult to suppress and resulted in low maize (Zea mays L.) and cowpea (Vigna unguiculata L.) yields. In contrast, leguminous covers were easily suppressed and resulted in good yields of maize and cowpea.

Beste (1983) discussed minimum-tillage studies performed on several vegetable crops using an overwintered, killed rye cover. Procedures such as fertilization, planting and residual herbicide applications were made without cultivation, but subsequently young plants were cultivated. Yields derived from minimum-till production of seeded tomatoes, snap beans, lima beans and sweet corn were generally found to be equal to or greater than the yields produced under conventional tillage. Young seedlings grown in minimum-till plots were sheltered from damage associated with wind erosion of soil. When sown without tillage, acceptable stand establishment often was not achieved by cultivars lacking early vigor.

"Living mulch" trials were performed by Nicholson and Wien (1983) in New York. Several cover crop species caused significant reductions in yield of cabbage and sweet corn which had been planted into established covers following strip tillage. Although sweet corn and cabbage yields were not affected by three cover crops in the first year, suppression of these cover crops prior to the second year of cropping was necessary to alleviate the competitive effects of the covers.

Litsinger and Ruhendi (1984) found that the best combination of cowpea insect pest control and high cowpea yield was achieved when cowpeas were established in plow furrows opened between alternate rows of rice stubble. The optimum rice stubble height was determined to be 20 to 25 cm tall.

Using mown legumes as living mulches, Altieri et al. (1985) conducted a study involving corn, tomatoes and cauliflower (Brassica oleracea L. var. botrytis). The results obtained indicated that leguminous covers were too competitive and crop yields were economically unsatisfactory.

Robinson (1985) compared the effects various combinations of no-till and tillage had on fieldbean (P. vulgaris) production. The least degree of weed control was experienced by zero tillage plots. Zero till plots consistently experienced low fieldbean yields regardless of the year to year variation in degree of weed competition experienced. The tillage combination most beneficial to average bean yield production consisted of no-till in the fall followed by moldboard or chisel plowing in the spring.

Morse and Seward (1986) made comparisons between conventional tillage and no-till with regard to the effects on fall broccoli (Brassica oleracea L. var. italica) and cabbage production in Virginia. No-till produced yields and head sizes in both vegetables equal to or greater than conventional tillage.

Petersen et al. (1986) contrasted no-till and strip-till with conventional tillage in Oregon sweet corn production. Due to cool spring weather and wet soils, the implementation of reduced tillage methods was limited. Lower early season soil temperatures and increased broadleaf weed competition with strip-till and no-till resulted in delayed plant development and reduced yields relative to yields from conventional till treatments.

Living mulches and cover crops in no-till vegetable production were tested by DeGregorio and Ashley (1986). Pod yields of snap beans from plots sown with any of the five kinds of covers were greater than yields of unweeded no-till control plots. However, cover crop treatments produced yields less than those obtained from weeded no-till and weeded conventional till controls.

Andow et al. (1986) grew cabbage interplanted with several living mulches and in bare-ground monocultures. Two leguminous covers were found to reduce marketable head weights in cabbage planted in established covers following strip tillage. However, the marketable head size of cabbage grown in two grassy covers was found to not be significantly different from cabbage grown in the bare-ground control.

Loy et al. (1987) compared vegetable productivity of conventional tillage to the productivity of strip-tillage of two cover types. Yields of pepper and winter squash (Cucurbita maxima L.) grown in 1.1 m strips of either cover type were found to be equivalent to the yields produced by conventional tillage. However, in the second year of the study both marketable and total pepper yields from the strip-tilled plots were lower than the conventional till treatment.

Shelby et al. (1988) compared tomato production in a no-till system to that in a conventional till system. Results from this study indicated that alternatives to conventional tillage techniques were feasible.

As evidenced by the preceding literature review, the comparisons that have been made between conventional-till and conservational-till have produced widely varied results with regard to vegetable crop yields. Contradictory reports have been made showing favorable results in yields derived from both conventional and conservational tillage methods. Reports demonstrating equivalent yields resulting from the practice of both tillage methods have also been made. The inconsistancies that exist among experimental results concerning conservational tillage practices can be attributed to a wide variety of factors. Soil type, type and kind of cover crop chosen, amount of cover residue produced, degree of suppression of cover crop, degree of tillage, weed control, type of vegetable grown and the season in which the cash crop is grown have all been associated with the success and/or failure of the conservational tillage techniques. As a result of conflicting reports and the various factors that influence the success rate of alternative tillage methods, the only way in which conservation tillage can be assessed for this geographic area is to conduct specific experiments under Oklahoma conditions.

CHAPTER III

SCREENING COVER CROPS FOR USE IN CONSERVATION TILLAGE SYSTEMS FOR VEGETABLES FOLLOWING SPRING PLOWING

Wendy A. Nelson, Brian A. Kahn, and Warren Roberts
Department of Horticulture and Landscape Architecture
Oklahoma State University
Stillwater, OK

Additional index words. groundcovers, grasses, legumes, low-till, minimum-till

Abstract: Several prospective cover crops were sown into 1 m^2 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. Kentucky bluegrass (*Poa pratensis* L.) and three fescues (*Festuca* sp.) 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. Glyphosate was ineffective in killing hairy vetch at both locations.

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 (Phillips et al., 1980; Unger and McCalla, 1980; Allmaras and Dowdy, 1985). 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 (Doss et al., 1981; Knavel and Herron, 1981; Beste, 1983; Robinson, 1985). Second, "living mulches" (Hughes and Sweet, 1979) generally have proven to be excessively competitive with interplanted vegetable crops (Nicholson and Wien, 1983; Altieri et al., 1985).

Our long-term goal was to develop a conservation tillage system for warm season vegetable production which did not exclude some tillage, and which utilized killed cover crops. The first step, and the objective of the present study, was to identify one or more cover crops which 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. We conducted monoculture screenings of several prospective cover crops 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 Severn 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. Supplemental fertilization was not used in Lane. Supplemental irrigation was not used at either location.

The cover crops were seeded by hand into 1 m^2 plots using normal pasture rates (Martin et al., 1976) shown in Table 1. Germination tests were conducted before planting each year and the seeding rates adjusted accordingly. Seeds were broadcast 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 ten 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 Moldenhauer (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 cm x 50 cm square. Weeds and cover crops within the boundaries of the square were cut by hand at soil level, separated accordingly, dried at 55C for at least 3 days, and weighed. Sampling occurred 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 at rates of 1.7 kg ha^{-1} (Bixby) or 2.2 kg ha^{-1} (Lane). Visual estimations of percent kill were made 18 and 24 days after treatment at Bixby and Lane, respectively. Ratings were made by two persons working independently and were averaged.

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 the four small grains, annual ryegrass, hairy vetch, and crimson clover (Table 2). The four small grains and annual ryegrass also provided the greatest degree of weed competition, with three of the four turfgrasses being found not significantly different from the weedy control. All covers reduced the amount of bare soil compared to the weedy control, with the greatest reductions obtained from annual ryegrass, rye, and hairy vetch (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 ten crops in 1988. Grassy covers tended to perform better than leguminous crops. Annual ryegrass and barley produced the greatest percentages of ground cover (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. The highest degree of weed competition was provided by the four small grains, annual ryegrass, crimson clover, and Austrian winter pea; hairy vetch was not significantly different from the weedy control. All covers reduced the amount of bare soil compared to the weedy control. All covers reduced the amount of bare soil compared to the weedy control, as in 1987, with annual ryegrass and barley plots containing the least exposed soil (Table 3). All crops produced weed:cover dry weight ratios <1.0, with six of the ten 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. The legumes were intermediate in degree of kill, except for hairy vetch which was tolerant to the herbicide (Table 3).

Lane, 1988. There was some difficulty with legume stand establishment; we were unable to determine the cause of this. Consequently, the four small grains and annual ryegrass produced the greatest percentages of ground cover and the greatest reductions in weed establishment (Table 4). Among the legumes, only hairy vetch gave significant reduction in ground cover due to weeds compared to the weedy control, 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 ten 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. The tallest crops were oats, rye, and annual ryegrass. 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).

When an overview of the three studies was made, 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. Crimson clover and hairy vetch were the best legumes, 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 utilized in a killed-cover conservation tillage system.

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

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

Table 2. Characteristics of cover crops grown in monoculture, 1 m^2 plots (Bixby, Okla., 1987).

Cover crop	% ground cover due to: Cover crop	% ground cover due to: Weeds	% bare soil	Dry wt weeds: dry wt cover ratio	Cover crop height (cm)
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

[z]Mean separation in columns by Waller-Duncan t-test, K ratio = 100.
[y]Mean height of weeds in control plots, for comparison with cover crop heights.

Table 3. Characteristics of cover crops grown in monoculture, 1 m^2 plots (Bixby, Okla., 1988).

Cover crop	% ground cover due to: Cover crop	Weeds	% bare soil	Dry wt weeds: dry wt cover ratio	Cover crop height (cm)	% kill by glyphosate
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

[z]Mean separation in columns by Waller-Duncan t-test, K ratio = 100.
[Y]Mean height of weeds in control plots, for comparison with cover crop heights.

Table 4. Characteristics of cover crops grown in monoculture, 1 m^2 plots (Lane, Okla., 1988).

Cover crop	% ground cover due to: Cover crop	% ground cover due to: Weeds	% bare soil	Dry wt weeds: dry wt cover ratio	Cover crop height (cm)	% kill by glyphosate
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 ab	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

[z]Mean separation in columns by Waller-Duncan t-test, K ratio = 100.
[y]Mean height of weeds in control plots, for comparison with cover crop heights.

LITERATURE CITED

Allmaras, R.R. and R.H. Dowdy. 1985. Conservation tillage systems and their adoption in the United States. Soil Tillage Res. 5:197-222.

Altieri, M.A., R.C. Wilson, and L.L. Schmidt. 1985. The effects of living mulches and weed cover on the dynamics of foliage- and soil-arthropod communities in three crop systems. Crop Protection 4(2):201-213.

Beste, C.E. 1983. No-tillage systems for vegetables and ornamentals. Proc. Northeastern Weed Sci. Soc. 37 (Suppl.):52-57.

Doss, B.D., J.L. Turner, and C.E. Evans. 1981. Influence tillage, nitrogen, and rye cover crop on growth and yield of tomatoes. J. Amer. Soc. Hort. Sci. 106:95-97.

Hoyt, G.D. and W.L. Hargrove. 1986. Legume cover crops for improving crop and soil management in the southern United States. HortScience 21:397-402.

Hughes, B.J. and R.D. Sweet. 1979. Living mulch: A preliminary report on grassy cover crops interplanted with vegetables. Proc. Northeastern Weed Sci. Soc. 33:109.

Knavel, D.E. and J.W. Herron. 1981. Influence of tillage system, plant spacing, and nitrogen on head weight, yield, and nutrient concentration of spring cabbage. J. Amer. Soc. Hort. Sci. 106:540-545.

Martin, J.H., W.H. Leonard, and D.L. Stamp. 1976. Principles of field crop production. 3rd ed. Macmillan, New York.

Moschler, W.W., G.M. Shear, D.L. Hallock, R.D. Sears, and G.D. Jones. 1967. Winter cover crops for sod-planted corn: Their selection and management. Agron. J. 59:547-551.

Nicholson, A.G. and H.C. Wien. 1983. Screening of turfgrasses and clovers for use as living mulches in sweet corn and cabbage. J. Amer. Soc. Hort. Sci. 108:1071-1076.

Phillips, R.E., R.L. Blevins, G.W. Thomas, W.W. Frye, and S.H. Phillips. 1980. No-tillage agriculture. Science

208:1108-1113.

Robinson, R.G. 1985. Tillage for sunflower control and for annual canarygrass and fieldbean production. Agron. J. 77:612-616.

Sloneker, L.L. and W.C. Moldenhauer. 1977. Measuring the amounts of crop residue remaining after tillage. J. Soil Water Conserv. 32:231-236.

Unger, P.W. and T.M. McCalla. 1980. Conservation tillage systems, p. 1-58. In: N.C. Brady (ed.). Advances in agronomy, vol. 33. Academic Press, New York.

CHAPTER IV

STRIP-TILLED FALL BROCCOLI PRODUCTION WITH GROUND COVERS PRODUCED BY RELAY INTERCROPPING INTO A SPRING BELL PEPPER CROP

Wendy A. Nelson and Brian A. Kahn
Department of Horticulture and Landscape Architecture
Oklahoma State University
Stillwater, Oklahoma

Additional index words. groundcovers, grasses, legumes, low-till, minimum-till

Abstract: Studies were conducted for two years to examine the effects of relay intercropping with various cover crops on yield of spring grown bell peppers (*Capsicum annuum* L.). Following termination of the spring crop, the covers were killed with glyphosate and used as residues into which a fall broccoli (*Brassica oleracea* L. var. *italica*) crop was transplanted. In 1988, crimson clover (*Trifolium incarnatum* L.) and annual ryegrass (*Lolium multiflorum* L.) were seeded on two dates into established bell peppers. The first seeding of crimson clover was too competitive and reduced marketable yields. No other treatments differed from conventional practices. Broccoli was transplanted in strip-tilled areas formerly occupied by peppers; however, broccoli stand establishment was unsuccessful. In 1989 a preplant-incorporated application of trifluralin was added as a herbicide treatment. Three covers [crimson clover, annual ryegrass and rye (*Secale cereale* L.)] were seeded into established peppers. Following the termination of the peppers, covers were killed with glyphosate, and former pepper areas were strip-tilled and planted with broccoli. Rye lowered total marketable pepper weight and both number and weight of cull peppers produced. All other treatments yielded results comparable to conventional methods. No cover crop residues adversely affected broccoli yields. Trifluralin reduced total weed weights compared to the control; however, weed control remained a major limiting factor in the success of this reduced tillage technique.

The benefits of conservation tillage techniques and the role of cover crops as an essential part of this type of system have been widely recognized and researched (Unger and McCalla, 1980; Fenster, 1984; Allmaras and Dowdy, 1985). Although agronomic uses of conventional till alternatives have been extensively investigated, the study of such systems for use in vegetable crops has been limited. Furthermore, the results obtained from studies using vegetables interplanted with cover crops as living mulches have generally tended to be negative due to excessive competition and yield reductions (Andow et al., 1986; DeGregorio and Ashley, 1986; Loy et al., 1987).

In Oklahoma an opportunity exists to produce two cash crops in one growing season by following a spring-planted warm season vegetable with a cool season vegetable grown in the fall. The presence of cover crop residues could help alleviate the detrimental affects of the high soil temperatures experienced during the establishment of the fall crop. However, a producer desiring to use this cropping system is faced with the dilemma of how to establish the cover residues without eliminating one of the cash vegetable crops or suffering possible reductions in yield if the cover is grown as a living mulch.

Relay intercropping is the production of more than one crop simultaneously for a portion of each crop's growing season (Andrews and Kassam, 1976). By adjusting the time period during which the crops overlap, this cropping system may be used to avoid some of the competitive effects associated with living mulch systems by providing a period of monoculture during the establishment of the spring crop. Following this monoculture period, cover crops would be intercropped with the vegetable and killed at the termination of the spring crop. The cover crop residues would then be available when a fall vegetable crop was transplanted.

In our experimental system, a spring crop of bell peppers was followed by a fall crop of broccoli. The objective of the study was to determine whether relay intercropping could be used to provide cover crop residues into which fall broccoli could be transplanted following strip-tillage, while maintaining levels of vegetable yield and quality equal to or greater than conventional production techniques.

Experiments were conducted in 1988 and 1989 at the Vegetable Research Station, Bixby, Okla. The soil was a Severn very fine sandy loam [coarse-silty, mixed (calcareous) thermic Typic Udifluvents]. Standard commercial foliar insecticides were applied as required. Sprinkler irrigation was utilized according to needs as determined from subjective soil observations.

1988. 'Early Calwonder' bell peppers were seeded into bulk benches in the greenhouse on 2 Mar. The field was prepared with a broadcast preplant-incorporated application of 60N-27P-50K (kg ha^{-1}). The pepper transplants were planted in the field on 20 Apr. at a 35 cm within-row spacing. Rows were 4 m long and spaced 1 m apart. At the time of planting, each transplant received about 200 ml of starter solution which provided 1078N-949P-895K (mg $liter^{-1}$) and 300 mg $liter^{-1}$ diazinon. The experimental design was a randomized complete block with four replications. All plots were cultivated on 2 May.

Two cover crops, crimson clover and annual ryegrass, were chosen from a list of promising covers screened in a related study. These covers were sown at rates of 2.2 and 3.1 g m^2, respectively (Martin et al., 1976). Rates were adjusted according to germination tests. Both covers were seeded by hand on two dates. The first seeding occurred on 18 May and was followed by a light cultivation of all plots, both seeded and non-seeeded. The pepper plants were just entering the anthesis stage on 18 May. On 3 June, a second seeding occurred which was followed by a light cultivation only of control plots and those plots seeded on this date. Young fruits were present on most pepper plants on 3 June.

Pepper harvests were conducted weekly beginning on 21 June and ending 2 Aug. with a total of seven harvests. Peppers were separated into marketable fruit and those culled due to blossom-end rot, sun scald, or other defects (such as poor shape or insect damage). Weights and numbers of both marketable and cull peppers were taken.

Volumetric moisture content of the soil to a 15 cm depth was measured using the IRAMS Analysis System

(Soilmoisture Equipment Corp., Santa Barbara, CA). Measurements were taken in the center of the aisle in each plot on 18 July and 2 Aug.

Hand weeding of an 8 m^2 area within all plots was performed on 23 June and 27 July. Any weeds removed were dried at 55C and weighed. Cover crop densities were measured using the rope-knot method (Sloneker and Moldenhauer, 1977) on 2 Aug. Following the density rating process, plots were sampled using a 50 cm x 50 cm sampling square. Covers and weeds within the boundaries of the square were cut by hand at soil level, separated accordingly, dried at 55C and weighed. Pepper plants were then removed from the field. Five pepper plants from each plot (excluding roots) were dried at 55C and weighed. Glyphosate at a rate of 1.7 kg ha^{-1} was applied to the plots on 10 Aug. On 18 Aug. an application of oxyfluorfen was made at a rate of 0.37 kg ha^{-1}.

Urea at a rate of 112 kg ha^{-1} N was broadcast over the former pepper rows and incorporated by strip-tillage on 17 Aug. Tillage was accomplished with one pass per row of a hand-guided rototiller, which tilled strips 50 cm wide at an average depth of 8 cm. 'Emperor' broccoli transplants with a rooting medium volume of about 18 cm^3 per plug were obtained from a commercial source. Transplants were placed in the field on 19 Aug. and given about 200 ml of starter solution containing 719N-316P-597K (mg $liter^{-1}$), respectively, plus 253 mg $liter^{-1}$ diazinon. Plots were reduced to 3 m in length and row locations were adjusted to avoid the areas sampled with the 0.25 m^2 square. Double-rows spaced 30 cm apart were used within the tilled strips, and plants were set at 30 cm apart within the rows. Most of the broccoli transplants died, so the study was replanted on 1 Sept. with transplants of 'Solid Blue 760' cabbage. The cabbage established successfully; however, marketable-sized heads were not produced before frost.

Sprinkler irrigations occurred on 22 Apr.; 6, 9, 18, 27 May; 3, 5, 8, 12, 24, 29 June; 4, 8, 14, 19, 21, 24, 25 Aug.; and 1 Sept.

1989. Based on the preliminary results obtained from the 1988 experiment, several modifications were made in 1989. Data collected from the previous year's study indicated that an alteration of the cover crop sowing date was necessary. Since covers from the first seeding date were too competitive with the pepper crop, and since covers from the second seeding date failed to produce sufficient cover crop growth, an intermediate date was chosen in 1989. The need for additional weed control was also evident from the results obtained in 1988. Thus, the study was modified to include the herbicide trifluralin as a variable. With the deletion of sowing date as a variable, an additional cover crop (rye) was added. The experimental design was a split-plot with three replications. Cover crops served as the main plot with herbicide as the subplot.

'Early Calwonder' bell peppers were seeded into bulk benches in the greenhouse on 1 Mar. The field was prepared with a broadcast preplant-incorporated application of 58N-26P-48K (kg ha^{-1}). A preplant-incorporated application of trifluralin at 420 kg ha^{-1} (75% of the normal rate) was applied to one-half of the total number of plots on 21 Apr. On 24 Apr. transplants were planted in 4 m long rows, spaced 1 m apart at a 35 cm within-row spacing. Each plant received about 200 ml of a starter solution which provided 1078N-949P-895K (mg $liter^{-1}$), respectively, in addition to 300 mg $liter^{-1}$ diazinon.

In 1989 the highest seeding rate suggested by Martin et al. (1976) was used to correspond with the modified sowing date (in 1988 the average recommended rate was used). Crimson clover, annual ryegrass, and rye were seeded at rates of 2.8, 3.4 and 12.6 g m^2, respectively. Rates again were adjusted according to germination tests. Only one sowing date (24 May) was utilized. The broadcast sowing of the covers was preceded by a sidedressing with 67 kg ha^{-1} N from urea and a light cultivation of all plots. The pepper plants were in the anthesis stage on 24 May, with some early fruit set.

Weekly harvests of peppers began on 20 June and concluded on 25 July. A total of six harvests were performed. Weights and numbers of marketable and cull peppers were recorded along with the reason for culling, as in 1988. Blossom-end rot was not evident in 1989.

The IRAMS Analysis System was used to measure soil moisture content. The volumetric moisture content to a depth of 15 cm was taken 28 June; 5, 13, 19 July; and 24 Aug. Readings from the aisle centers of all plots were taken on each date. However, on the day of broccoli transplanting (24 Aug.), an additional reading from within the strip-tilled rows was taken from each plot.

Weeds were removed by hand from an 8 m^2 area within all plots on 20 June and 18 July, dried at 55C and weighed. The densities of cover crops were estimated on 27 June and 25 July using the rope-knot method (Sloneker and Moldenhauer, 1977). Harvest of covers and weeds within a 50 cm x 50 cm sampling square occurred on 25 July. Covers were separated from weeds and both were dried at 55C and weighed. The removal of the pepper plants from the field also took place on 25 July. Five pepper plants from each plot (excluding roots) were dried at 55C and weighed. On 27 July, the entire experimental area was mowed at about 20 cm height to remove seed heads from covers and weeds. Plots were sprayed with glyphosate at a rate of 1.7 kg ha^{-1} on 17 Aug. Oxyfluorfen was applied on 23 Aug. at 0.37 kg ha^{-1}.

Urea at 112 kg ha^{-1} N was broadcast and incorporated during the strip-tillage operation into the areas formerly occupied by the bell pepper plants, as in 1988. These procedures were performed on 23 Aug. On 24 Aug., plug-type transplants of 'Premium Crop' broccoli which had been seeded in the greenhouse on 29 July were transplanted into the field. The rooting medium volume of each plug was about 18

cm^3. Plugs were placed at a 30 cm within row spacing in 3 m long double-rows spaced 30 cm apart. Rows within the plot were adjusted to avoid the areas sampled with the 0.25 m^2 square, as in 1988. Each transplant was given about 200 ml of a starter solution which supplied 719N-316P-597K (mg $liter^{-1}$) and 253 mg $liter^{-1}$ diazinon. Dead transplants and those lacking an apical meristem ("blind") were counted and replaced on 30 Aug. Broccoli plants were sidedressed with urea at rates of 56 kg ha^{-1} N on 18 Sept. and 28 kg ha^{-1} N on 4 Oct.

Broccoli harvests were conducted twice weekly beginning 24 Oct. and ending on 7 Nov. A total of five harvests were performed. At harvest, leaves were removed, stalks were trimmed to 20.5 cm from the top of the dome, and the heads were weighed. Classification of marketability and reason for culling were also noted.

Plants from each crop were sampled for N content. Bell pepper plants were sampled on 5 July. Four young, mature leaves from each of the ten data plants per plot were removed at the petiole-stem junction. Petioles were removed and discarded. On 12 Oct., broccoli petiole samples were removed prior to heading from three plants within the data double-row. The first visibly expanded leaf at the apex was noted on each plant; then proceeding basipetally, the sixth leaf was identified and severed from the plant. Leaf blades were stripped from the petioles. Both types of plant samples were dried at 70C, ground to pass a 20-mesh screen, and analyzed for percent N using the macro-Kjeldahl method (Association of Official Analytical Chemists, 1970).

Sprinkler irrigation was applied to the plots throughout the season. The specific dates of application were 24, 26, 29 Apr.; 24, 26, 30 May; 13 July; 25, 29, 31 Aug.; 8, 22 Sept.; and 4, 12, and 25 Oct.

Data from the 1988 and 1989 experiments were subjected to analysis of variance procedures. Each cover crop treatment was compared to the control using Dunnett's test at $\underline{P} = 0.05$. Comparisons among cover crop treatments were made using single degree of freedom orthogonal contrasts.

1988. No significant differences were found in soil moisture content on 18 July or 2 Aug. (Table 5).

Marketable peppers were compared according to number produced, weight, average fruit weight and percent harvested after two picks (Table 6). The first seeding date (18 May) of crimson clover was the only treatment that significantly reduced the marketable yield of bell peppers when contrasted to the pepper yields from conventional production techniques. Fewer marketable peppers were harvested from plots of both covers sown on 18 May than from the corresponding plots sown on 3 June. This suggested greater competition from the covers sown on 18 May. Percent harvested after two picks was higher for pepper plants grown in plots of crimson clover seeded on 18 May when compared to either plants from the control plots or plants from plots of crimson clover seeded on 3 June. This reflected the reduced yields from the 18 May crimson clover plots.

Cull peppers were evaluated on the basis of number, weight and reason for culling (Table 7). Only one significant difference was found. Pepper plants from the 18 May seeding of crimson clover had fewer fruits culled for reasons classified as "other" when compared to plants from the 3 June seeding of this cover. "Other" refers to defects not associated with blossom-end rot or sun scald, such as deformed fruit or insect damage.

Treatment effects on the dry weights of pepper plants, cover crops and total weeds harvested from each plot are shown in Table 8. Pepper plants grown in crimson clover plots sown on 18 May weighed less than those grown in control plots, reflecting the competitive effects of the crimson clover. Only the first seeding dates of both covers produced significantly more cover than the bare soil control. Thus, the 3 June seeding produced inadequate cover crop growth. Overall, crimson clover produced more cover than annual ryegrass. Plots from the 18 May seeding of both covers contained more weeds than control plots. The 18 May plots also contained more weeds than corresponding plots from the 3 June seeding. These weed reductions can be partially attributed to the additional cultivation received by the newly sown plots and the controls on 3 June.

These results provided some preliminary evidence that yield and quality could be maintained under systems other than conventional methods. The competitive effects of the first seeding date of crimson clover were manifest in reductions in marketable pepper yield and in pepper plant dry weight. However, due to the limited number of moisture readings taken and the nonsignificance found among the two readings which were performed, this competition cannot be attributed to cover-induced moisture losses. Nitrogen content of plants was not measured so only speculation can be made with regard to competition for soil nitrogen.

The subsequent fall crop did not mature; thus, no results were obtained, and conclusions cannot be made concerning this portion of the experiment.

1989. Soil moisture was lower in annual ryegrass plots than in rye plots when the first two moisture readings were taken (Table 9). An interaction of cover x herbicide was also evident at the time of the second reading (Table 10). The soil moisture contents of control and annual ryegrass plots were unaffected by herbicide treatment. Crimson clover plots without herbicide contained more moisture than clover plots with herbicide. In contrast, rye plots with the herbicide treatment contained a higher percent moisture than rye plots not treated with herbicide. Readings on the remaining dates did not produce any significant differences. Our findings differ from those of Knavel and Herron (1981), who found that soil moisture in a no-till system was always higher than that for conventionally-tilled soil when cabbage was grown in killed winter wheat. However, our soil moisture data were from plots with living cover crops (except on 24 Aug.).

Marketable pepper numbers and the average fruit weight were not affected by any treatment (Table 11). Total marketable fruit weight produced by plants grown with rye was less than the weight produced by control plants. When rye was contrasted to annual ryegrass, the percent harvested after two picks was higher in rye plots.

Peppers unsuitable for sale were again evaluated on the basis of number, weight and reason for culling (Table 12). Rye significantly reduced the total number, weight and number of "other" culls when compared to the control.

Dry weight comparisons showed that the average weight of a pepper plant from rye plots was lower than that of a plant from both control and annual ryegrass plots (Table 13). All cover crops produced significantly more cover than the bare soil control. Crimson clover when contrasted to the other two cover crops produced the greatest amount of cover. Crimson clover and rye both reduced the amount of weeds contained within the plots when compared to the control. Plots treated with trifluralin showed reductions in both cover crop and total weed dry weights when contrasted to plots not receiving the herbicide application (Table 13).

Marketable heads of broccoli produced were compared on the basis of number, weight, average head weight, days to first harvest and percent harvested after two picks (Table 14). Only one significant difference attributable to cover crop effects was found: annual ryegrass increased the percent harvested after two picks when compared to rye. Trifluralin-treated plants were harvested an average of one day earlier than control plants. No significant differences were found in the broccoli cull numbers or weights (Table 14). The absence of significant differences in broccoli yields is similar to the results obtained by Orzolek and Carroll (1978). They found that yields of carrots produced conventionally did not differ from carrot yields produced in a no-till system using a killed rye cover. Wilson et al. (1982) also found that cowpea yields were significantly higher from plants established in strip-tilled rows of several covers which had been chemically suppressed than from plants established in conventionally-tilled plots. However, our findings contrast those of Doss et al. (1981) who reported that marketable yields of tomatoes tended to be greater on no-rye plots than on plots with a killed rye cover.

Percent nitrogen from both pepper plants and broccoli plants was measured in 1989 (Table 15). Pepper nitrogen levels were lower in plants grown with rye when compared to control plants or those grown with annual ryegrass. The average nitrogen content of plants grown with grassy covers (annual ryegrass and rye) also was lower than that of plants grown with crimson clover. Broccoli nitrogen contents were not significantly affected by any treatment. Mullins et al. (1980) found that tillage method did not affect the petiole

N concentration in snap beans or lima beans grown under various tillage conditions. Knavel et al. (1977) reported findings that (with the exception of rye's influence on pepper N content) are opposite from the results of this study. They found that conventionally tilled crops generally contained more nitrogen than no-till crops.

In 1989, rye was the only cover treatment to affect pepper yield and quality. Rye decreased the total weight of marketable peppers produced, although it did not significantly reduce the count or average fruit weight. As in 1988, all covers did not increase cull production. Rye competition can also be demonstrated in the significant reduction in pepper plant dry weights when compared to the control and to annual ryegrass. The seeding date modification proved beneficial, in that all cover crops produced more ground cover than the control without reducing yield. However, crimson clover and rye did compete with weeds, resulting in significantly lower total weed dry weights than those from control plots. The trifluralin application reduced weed weight by approximately 68% from the control. Moisture readings were taken more frequently than in the previous year's study. However, since significant differences were limited to only one contrast (AR vs. RY) on only two occasions, moisture stress as a result of rye growth could not be confirmed as the cause of reduced total marketable pepper weights when rye was contrasted to control plots. On the other hand, competitive effects associated with rye could be at least partially attributed to increased competition for soil nitrogen. Another possible explanation is an allelopathic effect of rye residues on the broccoli plants (Barnes et al., 1986).

In conclusion, the results from the 1988 study indicated that the first seeding date of crimson clover did not achieve the objective of maintaining marketable yield and quality. Furthermore, the second seeding date did not provide enough cover for the following fall crop. Following the adjustments made, the 1989 study provided evidence that the integration of conservation tillage techniques with vegetable production is feasible. Supplemental nitrogen reduced cull pepper production compared to 1988. With the exception of rye, all covers did not adversely affect pepper yield or quality when compared to conventional practices. All covers increased residue on the soil surface (compared to bare soil) prior to transplanting the fall crop. Cover crops also did not negatively affect the fall crop. Although the addition of the herbicide treatment reduced weeds, it is clear that for a system of this nature to be deemed a total success, further weed control practices must be implemented.

Table 5. Main effects of cover crops on volumetric moisture content in the top 15 cm of soil (Bixby, Okla., 1988).

Cover crop	Soil moisture content (%) 18 July	2 Aug.
Control	23.2	27.8
Crimson clover (V1)[z]	23.3	27.6
Crimson clover (V2)	20.8	28.0
Annual ryegrass (R1)	18.9	27.4
Annual ryegrass (R2)	21.4	27.6
	Contrasts	
Dunnett's test	NS	NS
Ryegrass vs. clover	NS	NS
R1 vs. R2	NS	NS
V1 vs. V2	NS	NS

[z]V1 and R1 signify 18 May seeding, and V2 and R2 signify 3 June seeding.
[NS]Nonsignificant

Table 6. Main effects of cover crops on bell pepper yield (Bixby, Okla., 1988).

Cover crop	Marketable peppers: Count (thousands/ha)	Marketable peppers: Weight ($Mg \cdot ha^{-1}$)	Marketable peppers: Average fruit wt (g)	Peppers harvested after two picks (%)
Control	146	15.8	107	47
Crimson clover (V1)[z]	81*	9.2*	114	81*
Crimson clover (V2)	134	15.0	113	58
Annual ryegrass (R1)	100	12.3	122	66
Annual ryegrass (R2)	148	16.4	112	59
		Contrasts		
Dunnett's test[y]	*	*	NS	*
Ryegrass vs. clover	NS	NS	NS	NS
R1 vs. R2	*	NS	NS	NS
V1 vs. V2	**	*	NS	*

[z]V1 and R1 signify 18 May seeding, and V2 and R2 signify 3 June seeding.
[y]Within columns, asterisks in the body of the table indicate means which differ significantly from the control according to Dunnett's test at the 5% level.
NS,*,**Nonsignificant or significant at the 5% or 1% levels, respectively.

Table 7. Main effects of cover crops on bell pepper culls (Bixby, Okla., 1988).

Cover crop	Cull peppers		Reason for culling[z]		
	Count (thousands/ha)	Weight ($Mg \cdot ha^{-1}$)	BER (thousands/ha)	Scald (thousands/ha)	Other (thousands/ha)
Control	236	13.5	9	140	86
Crimson clover (V1)[y]	154	7.6	9	103	43
Crimson clover (V2)	240	11.1	9	117	114
Annual ryegrass (R1)	204	10.5	9	143	54
Annual ryegrass (R2)	195	10.5	6	109	80
			Contrasts		
Dunnett's test	NS	NS	NS	NS	NS
Ryegrass vs. clover	NS	NS	NS	NS	NS
R1 vs. R2	NS	NS	NS	NS	NS
V1 vs. V2	NS	NS	NS	NS	**

[z]Reason for culling: blossom end rot (BER), sun scald and other (defects not attributed to BER or scald such as deformed fruit, etc.), respectively.
[y]V1 and R1 signify 18 May seeding, and V2 and R2 signify 3 June seeding.
NS,**Nonsignificant or significant at the 1% level, respectively.

Table 8. Main effects of cover crops on pepper plant, cover crop, and total weed dry weights (Bixby, Okla., 1988).

	Dry weights		
Cover crop	Peppers (g/plant)	Cover crops ($g \cdot m^2$)	Weeds ($g \cdot m^2$)
Control	78	0	14
Crimson clover (V1)[z]	56*	216*	79*
Crimson clover (V2)	72	144	13
Annual ryegrass (R1)	68	153*	68*
Annual ryegrass (R2)	79	40	23
		Contrasts	
Dunnett's test[y]	*	*	*
Ryegrass vs. clover	NS	*	NS
R1 vs. R2	NS	NS	*
V1 vs. V2	NS	NS	*

[z]V1 and R1 signify 18 May seeding, and V2 and R2 signify 3 June seeding.
[y]Within columns, asterisks in the body of the table indicate means which differ significantly from the control according to Dunnett's test at the 5% level.
NS,*Nonsignificant or significant at the 5% level, respectively.

Table 9. Main effect of cover crops on volumetric moisture content in the top 15 cm of soil (Bixby, Okla., 1989).[z]

Cover crop	Soil moisture content (%)					
	Within aisle					Within row
	28 June	5 July	13 July	19 July	24 Aug.	24 Aug.
Control	27.7	22.3	19.1	24.1	17.1	15.1
Crimson clover (CC)	27.3	19.7	13.6	23.8	18.9	15.3
Annual ryegrass (AR)	26.5	18.6	16.4	24.8	19.5	16.4
Rye (RY)	30.4	23.8	17.1	24.0	20.4	18.2
			Contrasts			
Dunnett's test	NS	NS	NS	NS	NS	NS
CC vs. (AR+RY)	NS	NS	NS	NS	NS	NS
AR vs. RY	*	*	NS	NS	NS	NS
Cover x herbicide	NS	*[Y]	NS	NS	NS	NS

[z]Main effect of herbicide was nonsignificant at the 5% level.
[Y]Interaction is detailed in Table 10.
NS,*Nonsignificant or significant at the 5% level, respectively.

Table 10. The interaction of cover crop and herbicide treatments on soil moisture content 5 July, 1989 (Bixby, Okla.).

Cover crop	Soil moisture content (%)	
	No herbicide	Trifluralin
Control	22.4ab[z]	22.1ab
Crimson clover (CC)	22.3ab	17.0c
Annual ryegrass (AR)	17.2c	20.1bc
Rye (RY)	21.0bc	26.5a

[z]Mean separation by interaction LSD, $\underline{P}$=0.05; LSD=4.7.

Table 11. Main effects of cover crops on bell pepper yield (Bixby, Okla., 1989).[z]

Cover crop	Marketable peppers: Count (thousands/ha)	Marketable peppers: Weight ($Mg \cdot ha^{-1}$)	Marketable peppers: Average fruit wt (g)	Peppers harvested after two picks (%)
Control	189	23.3	124	27
Crimson clover (CC)	167	21.0	127	30
Annual ryegrass (AR)	150	17.8	120	29
Rye (RY)	120	14.7*	125	45
		Contrasts		
Dunnett's test[y]	NS	*	NS	NS
CC vs. (AR+RY)	NS	NS	NS	NS
AR vs. RY	NS	NS	NS	*

[z]Main effects of herbicide and cover crop x herbicide interactions were nonsignificant at the 5% level.
[y]Within columns, asterisks in the body of the table indicate means which differ significantly from the control according to Dunnett's test at the 5% level.
NS,*Nonsignificant or significant at the 5% level, respectively.

Table 12. Main effects of cover crops on bell pepper culls (Bixby, Okla., 1989).[z]

Cover crop	Cull peppers: Count (thousands/ha)	Cull peppers: Weight ($Mg \cdot ha^{-1}$)	Reason for culling[y]: Scald (thousands/ha)	Reason for culling[y]: Other (thousands/ha)
Control	112	8.1	66	49
Crimson clover (CC)	93	6.2	57	37
Annual ryegrass (AR)	84	6.3	54	31
Rye (RY)	69*	4.4*	49	20*
Contrasts				
Dunnett's test[x]	*	*	NS	*
CC vs. (AR+RY)	NS	NS	NS	NS
AR vs. RY	NS	NS	NS	NS

[z]Main effects of herbicide and cover crop x herbicide interactions were nonsignificant at the 5% level.
[y]Reason for culling sun scald and other (defects not attributed to scald such as deformed fruit), respectively.
[x]Within columns, asterisks in the body of the table indicate means which differ significantly from the control according to Dunnett's test at the 5% level.
NS,*Nonsignificant or significant at the 5% level, respectively.

Table 13. Main effects of cover crops and trifluralin on pepper plant, cover crop, and total weed dry weights (Bixby, Okla., 1989).[z]

Treatment	Dry weights: Peppers (g/plant)	Dry weights: Cover crops ($g \cdot m^2$)	Dry weights: Weeds ($g \cdot m^2$)
Cover crop			
Control	97	0	66
Crimson clover (CC)	84	290*	25*
Annual ryegrass (AR)	89	172*	27
Rye (RY)	60*	221*	14*
		Contrasts	
Dunnett's test[y]	*	*	*
CC vs. (AR+RY)	NS	*	NS
AR vs. RY	**	NS	NS
Herbicide			
Control	85	191	50
Trifluralin	80	151	16
Main effect	NS	*	**

[z]Cover crop x herbicide interaction was nonsignificant at the 5% level.
[y]Within columns, asterisks in the body of the table indicate means which differ significantly from the control according to Dunnett's test at the 5% level.
NS,*,**Nonsignificant or significant at the 5% or 1% levels, respectively.

Table 14. Main effects of cover crops and trifluralin on broccoli transplant replacement and yield characteristics (Bixby, Okla., Fall 1989).[z]

	Transplants replaced (thousand/ha)	Marketable heads Count (thousands/ha)	Marketable heads Weight ($Mg \cdot ha^{-1}$)	Marketable heads Weight (g)	Days to first harvest[y]	Heads harvested after two picks (%)	Cull heads (thousands/ha)
Cover crop							
Control	14	87	18.1	209	63	46	22
Crimson clover (CC)	29	84	16.0	191	62	39	56
Annual ryegrass (AR)	23	89	16.7	187	63	44	11
Rye (RY)	20	88	17.1	194	62	29	56
Contrasts							
Dunnett's test	NS	NS	NS	NS	NS	NS	NS
CC vs. (AR+RY)	NS	NS	NS	NS	NS	NS	NS
AR vs. RY	NS	NS	NS	NS	NS	*	NS
Herbicide							
Control	20	86	16.5	192	63	43	44
Trifluralin	23	88	17.4	199	62	36	28
Main effect	NS	NS	NS	NS	*	NS	NS

[z]Cover crop x herbicide interaction was nonsignificant at the 5% level.
[y]Calculated from date of field planting.
[NS,*]Nonsignificant or significant at the 5% level, respectively.

Table 15. Main effects of cover crop on bell pepper and broccoli nitrogen contents (Bixby, Okla., 1989).[z]

Cover crop	Nitrogen content (%)	
	Peppers	Broccoli
Control	4.5	4.0
Crimson clover (CC)	4.2	4.0
Annual ryegrass (AR)	4.2	3.9
Rye (RY)	3.2*	3.7
	Contrasts	
Dunnett's test[y]	*	NS
CC vs. (AR+RY)	*	NS
AR vs. RY	**	NS
Cover x herbicide	NS	NS

[z]Main effect of herbicide was nonsignificant at the 5% level.

[y]Within columns, asterisks in the body of the table indicate means which differ significantly from the control according to Dunnett's test at the 5% level.

NS,*,**Nonsignificant or significant at the 5% or 1% levels, respectively.

LITERATURE CITED

Allmaras, R.R. and R.H. Dowdy. 1985. Conservation tillage systems and their adoption in the United States. Soil & Tillage Res. 5:197-222.

Andow, D.A., A.G. Nicholson, H.C. Wien, and H.R. Willson. 1986. Insect populations on cabbage grown with living mulches. Environ. Entomol. 15(2):293-299.

Andrews, D.J. and A.H. Kassam. 1976. The importance of multiple cropping in increasing world food supplies, p. 1-10. In: R.I. Papendick, R.A. Sanchez and G.B. Triplett (eds.). Multiple cropping. ASA Spec. Pub. No. 27. American Society of Agronomy, Madison, Wisconsin.

Association of Official Analytical Chemists. 1970. Official methods of analysis. 11th ed. Washington, D.C.

Barnes, J.P., A.R. Putnam, and B.A. Burke. 1986. Allelopathic activity of rye (Secale cereale L.), p. 271-286. In: A.R. Putnam and C.S. Tang (eds.). The science of allelopathy. Wiley-Interscience, New York.

DeGregorio R.E. and R.A. Ashley. 1986. Screening living mulches/cover crops for no-till snap beans. Proc. Northeastern Weed Sci. Soc. 40:87-91.

Fenster, C.R. 1984. Merits of conservation tillage, p. 11-16. In: Great Plains Agricultural Council. Proceedings of the Great Plains conservation tillage symposium, North Platte, Neb., 21-23 Aug. 1984. Pub. No. 110.

Loy, S.J.W., L.C. Peirce, G.O. Estes, and O.S. Wells. 1987. Productivity in a strip tillage vegetable production system. HortScience 22(3):415-417.

Martin, J.H., W.H. Leonard, and D.L. Stamp. 1976. Principles of field crop production. 3rd ed. Macmillan, New York.

Mullins, C.A., F.D. Tompkins, and W.L. Parks. 1980. Effects of tillage methods on soil nutrient distribution, plant nutrient absorption, stand, and

Effects of tillage methods on soil nutrient distribution, plant nutrient absorption, stand, and yields of snap beans and lima beans. J. Amer. Soc. Hort. Sci. 105:591-593.

Sloneker, L.L. and W.C. Moldenhauer. 1977. Measuring the amounts of crop residue remaining after tillage. J. Soil Water Conserv. 32:231-236.

Unger, P.W. and T.M. McCalla. 1980. Conservation tillage systems, p. 1-58. In: N.C. Brady (ed.). Advances in agronomy, vol. 33. Academic Press, New York.

Wilson, G.F., R. Lal, and B.N. Okigbo. 1982. Effects of cover crops on soil structure and on yield of subsequent arable crops grown under strip tillage on an eroded Alfisol. Soil & Tillage Res. 2:233-250.

A SELECTED BIBLIOGRAPHY

1. Allmaras, R.R. and R.H. Dowdy. 1985. Conservation tillage systems and their adoption in the United States. Soil & Tillage Res. 5:197-222.

2. Altieri, M.A., R.C. Wilson, and L.L. Schmidt. 1985. The effects of living mulches and weed cover on the dynamics of foliage- and soil-arthropod communities in three crop systems. Crop Protection 4(2):201-213.

3. Andow, D.A., A.G. Nicholson, H.C. Wien, and H.R. Willson. 1986. Insect populations on cabbage grown with living mulches. Environ. Entomol. 15(2):293-299.

4. Andrews, D.J. and A.H. Kassam. 1976. The importance of multiple cropping in increasing world food supplies, p. 1-10. In: R.I. Papendick, R.A. Sanchez, and G.B. Triplett (eds.). Multiple cropping. ASA Spec. Pub. No. 27. American Society of Agronomy, Madison, Wisconsin.

5. Barnes, J.P., A.R. Putnam, and B.A. Burke. 1986. Allelopathic activity of rye (Secale cereale L.), p. 271-286. In: A.R. Putnam and C.S. Tang (eds.). The science of allelopathy. Wiley-Interscience, New York.

6. Beste, C.E. 1973. Evaluation of herbicides in no-till planted cucumbers, tomatoes, and lima beans. Proc. Northeastern Weed Sci. Soc. 27:232-239.

7. Beste, C.E. 1983. No-tillage systems for vegetables and ornamentals. Proc. Northeastern Weed Sci. Soc. 37(Suppl.):52-57.

8. DeGregorio, R.E. and R.A. Ashley. 1986. Screening living mulches/cover crops for no-till snap beans. Proc. Northeastern Weed Sci. Soc. 40:87-91.

9. Doss, B.D., J.L. Turner, and C.E. Evans. 1981. Influence of tillage, nitrogen, and rye cover crop on growth and yield of tomatoes. J. Amer. Soc. Hort. Sci. 106:95-97.

10. Fenster, C.R. 1884. Merits of conservation tillage, p. 11-16. In: Great Plains Agricultural Council. Proceedings of the Great Plains conservation tillage

symposium, North Platte, Neb., 21-23 Aug. 1984. Pub. No. 110.

11. Hoyt, G.D. and W.L. Hargrove. 1986. Legume cover crops for improving crop and soil management in the southern United States. HortScience 21:397-402.

12. Hughes, B.J. and R.D. Sweet. 1979. Living mulch: A preliminary report on grassy cover crops interplanted with vegetables. Proc. Northeastern Weed Sci. Soc. 33:109.

13. Knavel, D.E., J. Ellis, and J. Morrison. 1977. The effects of tillage systems on the performance and elemental absorption by selected vegetable crops. J. Amer. Soc. Hort. Sci. 102:323-327.

14. Knavel, D.E. and J.W. Herron. 1981. Influence of tillage system, plant spacing, and nitrogen on head weight, yield, and nutrient concentration of spring cabbage. J. Amer. Hort. Sci. 106:540-545.

15. Loy, S.J.W., L.C. Peirce, G.O. Estes, and O.S. Wells. 1987. Productivity in a strip tillage vegetable production system. HortScience 22(3):415-417.

16. Martin, J.H., W.H. Leonard, and D.L. Stamp. 1976. Principles of field crop production. 3rd ed. Macmillan, New York.

17. Moschler, W.W., G.M. Shear, D.L. Hallock, R.D. Sears, and G.D. Jones. 1967. Winter cover crops for sod-planted corn: Their selection and management. Agron. J. 59:547-551.

18. Mullins, C.A., F.D. Tompkins, and W.L. Parks. 1980. Effects of tillage methods on soil nutrient distribution, plant nutrient absorption, stand, and yields of snap beans and lima beans. J. Amer. Soc. Hort. Sci. 105:591-593.

19. Ndon, B.A. and R.G. Harvey. 1981. Influence of herbicides and tillage on sweet corn double cropped after peas. Agron. J. 73:791-795.

20. Nicholson, A.G. and H.C. Wien. 1983. Screening of turfgrasses and clovers for use as living mulches in sweet corn and cabbage. J. Amer. Soc. Hort. Sci. 108:1071-1076.

21. Orzolek, M.D. and R.B. Carroll. 1978. Yield and secondary root growth of carrots as influenced by tillage system, cultivation, and irrigation. J. Amer. Soc. Hort. Sci. 103:236-239.

22. Petersen, K.L., H.J. Mack, and D.E. Booster. 1986. Effect of tillage on sweet corn development and yield. J. Amer. Soc. Hort. Sci. 111:39-42.

23. Phillips, R.E., R.L. Blevins, G.W. Thomas, W.W. Frye, and S.H. Phillips. 1980. No-tillage agriculture. Science 208:1108-1113.

24. Putnam, A.R. 1972. Efficacy of a zero-tillage cultural system for asparagus produced from seed and crowns. J. Amer. Soc. Hort. Sci. 97:621-624.

25. Robinson, R.G. 1985. Tillage for sunflower control and for annual canarygrass and fieldbean production. Agron. J. 77:612-616.

26. Unger, P.W. and T.M. McCalla. 1980. Conservation tillage systems, p. 1-58. In: N.C. Brady (ed.). Advances in agronomy, vol. 33. Academic Press, New York.

27. Wilson, G.F., R. Lal, and B.N. Okigbo. 1982. Effects of cover crops on soil structure and on yield of subsequent arable crops grown under strip tillage on an eroded Alfisol. Soil & Tillage Res. 2:233-250.

VITA

Wendy A. Nelson

Candidate for the Degree of

Master of Science

Thesis: COVER CROP SCREENING FOR CONSERVATION TILLAGE AND A PRELIMINARY REPORT ON RELAY INTERCROPPING FOR VEGETABLE PRODUCTION IN OKLAHOMA

Major Field: Horticulture

Biographical:

Personal Data: Born in Tulsa, Oklahoma, March 4, 1965, the daughter of Brad G. and Linda D. Nelson.

Education: Graduated from Chelsea High School, Chelsea, Oklahoma, in May, 1983; received Bachelor of Science Degree in Horticulture from Oklahoma State University in December, 1987; completed requirements for the Master of Science degree at Oklahoma State University in July, 1990.

Professional Experience: Field Assistant, Oklahoma State Univerisity Vegetable Research Station, Bixby, Okla., May, 1987 to August, 1987; Greenhouse worker, Oklahoma State University Research Greenhouses, September, 1987 to December, 1987; Research Assistant, Department of Horticulture and Landscape Architechture, Oklahoma State University, January, 1988 to August 1989; Teaching Assistant Department of Horticulture and Landscape Architecture, Oklahoma State University, August, 1989 to December, 1989; Research Assistant, Department of Horticulture and Landscape Architecture, Oklahoma State University, January, 1990 to May, 1990.