Vegetable Production with Conservation Tillage, Cover Crops and Raised Beds

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INTRODUCTION

In southeastern Oklahoma, soils often have a sandy topsoil and a clay or clay loam subsoil. A typical soil at the Wes Watkins Agricultural Research and Extension Center (WWAREC) at Lane, Oklahoma, is a Bernow fine-loamy, siliceous, thermic Glossic Paleudalf. With this soil, the A horizon is a fine sandy loam, approximately 30 to 35 cm deep, with a percolation rate of 5.1 to 15.2 cm/hr. The B horizon is a sandy clay loam, 1.25 to 1.65 m deep, with a percolation rate of 1.5to 5.1 cm/hr.

Rainfall at WWAREC averages over 100 cm/year. Distribution is erratic, and rainfall in excess of 17 cm was received in a five-day period during both 1989 and 1990. During winter and spring months, the water table is often within 60 cm of the soil surface. With this combination of rainfall and soil conditions, the soil can become saturated during periods of heavy rainfall, and the surface may at times be under water. In order to combat this problem of excessive moisture, vegetable producers are encouraged to grow all crops on raised beds. Bed size and shape vary, but a typical bed is 0.9 m wide and 0.2 m tall. For early spring crops, the soil in the spring is often too wet to allow the use of heavy machinery to till the soil and form the raised beds. An ideal situation would be to form raised beds in the fall and then plant the vegetable crop into the beds in the following spring. However, the sandy loam topsoil is subject to erosion from both wind and water during the winter months. In order to preserve the height and shape of the raised beds, cover crops are being sown on the beds in the fall. The covers are allowed to over-winter from October to March, and then vegetables are planted into the beds without additional tillage in the spring.

Cover crops are an integral part of conservation tillage systems that have been proven effective at reducing soil erosion (Papendick and Elliott, 1984). Most of the work with conservation tillage has been done with agronomic crops, but some work has also been done with vegetables. There are contrasting results concerning the effects of conservation tillage methods and cover crops on the yield of vegetable crops. Knave1 and Herron (1981) showed that spring cabbage yields in Kentucky were reduced using no-tillage methods when compared to conventional tillage. In contrast, yields of fall cabbage were increased with the no-tillage method in Virginia (Morse et al., 1982). Morse and Seward (1986) in Virginia considered rye to be an effective mulch crop for no-tillage production of fall cabbage. In Oklahoma a screening test to determine the ability of various cover crops to provide a quick, dense soil cover was conducted (Nelson et al., 1991). From this initial study, rye (Secale ***cereale)*** and hairy vetch (Vicia villosa) were chosen for further experimentation.

Conservation tillage and cover crops may affect insect populations in resultant vegetable crops, but the results are inconclusive. Phillips et al. (1980) showed that crops grown with conservation tillage may require higher inputs of pesticides, but Lockeretz et al. (1984) showed that crop residues can also increase beneficial biological control agents that may reduce insect pests. Reduced tillage methods have been shown to lower certain insect pest populations on certain vegetable crops (Zehnder and Linduska, 1987). There is little information concerning interactions among cover crops, nitrogen (N), crop yields and insects.

MATERIALS AND METHODS

Studies were conducted at Lane, Oklahoma, in 1988, 1989 and 1990 with broccoli, cabbage, sweet corn and tomatoes to determine the effects of soil covers and N fertilization on crop yield, insect populations and insect damage by the primary pests of each crop. Numerous experiments were conducted with both rye and hairy vetch, with the covers being sown during both the fall and spring. At all times, the soil was tilled prior to seeding, and raised beds were formed. The beds were approximately 6.1 m long and 0.9 m wide on 1.8-m centers and were approximately 0.2 m high at the time of formation. Covers were planted on top of and between the beds. At all times, a bare soil treatment was included in the experimental design to serve as a comparison with the cover crop treatments.

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In April 1988 raised beds were either seeded with rye or hairy vetch or left as bare ground. Cover crops were allowed to grow during the summer. In the fall, prior to planting the vegetable crops, glyphosate was applied to all plots. A narrow band approximately 30 cm wide was tilled in the center of each row and planted with broccoli. Each soil cover treatment received each of four N rates (44, 90, 134 or 179 kg/ha). A repeat experiment was initiated in the spring of 1989, when rye and hairy vetch were planted. Broccoli was again planted into the cover crops in the fall of 1989.

In October 1988 additional plots were either seeded with rye or hairy vetch or left as bare ground. In the spring of 1989, these soil cover treatments received each of four N rates (44, 90, 134or 179 kg/ha). Glyphosate was applied to all plots prior to planting the cash crop. There was no tillage. Cabbage, sweet corn and tomatoes were planted into the covers during the spring of 1989.

In October 1989 plots similar to those of the previous year were either seeded with rye or left as bare ground. In the spring of 1990, N was applied at 34, 101, 168, 235 or 302 kg/ha. There was no tillage. The rye was not killed with an herbicide but was instead allowed to seed and die naturally. Cabbage, sweet corn and tomatoes were planted into the covers during the spring of 1990.

Each crop was surveyed weekly or twice weekly for the presence of insect pests. In addition, the quantity and quality of the harvested commodity (fruit, heads or ears) were evaluated at the end of the season. Since a primary use of cover crops is to protect the soil from erosion, the height of the raised beds was measured shortly after the beds were formed, and subsequent measurements were taken periodically throughout the duration of the experiment, with the final bed height measurement being taken when the cash crop was harvested.

RESULTS

In general, the height of raised beds in the bare soil plots was not maintained as well as the height of the beds in plots covered with rye and vetch. Plots covered with rye were generally the tallest beds at the end of the experiment while the height of the plots covered with vetch was between the heights of the bare soil and rye-covered plots. This information supports the supposition that cover crops will reduce the severity of soil erosion.

In most experiments, the highest yields of cash crops occurred with bare soil plots, and the lowest yields occurred with the rye-covered plots. With each crop, there was a positive yield response to increasing rates of N fertilizer. The response was linear with tomatoes and sweet corn. With cabbage, the response was linear in 1989 and quadratic in 1990, with the highest yield occurring at the 168-kg/ha N rate.

In general, there was less difference in yield between the bare soil and the rye-covered plots at the higher rates of N than at the lower rates of N. The results varied somewhat from one experiment to another, but the general trend indicated that crops grown in rye-covered plots and fertilized at low levels of N will have a lower yield than will any other treatments. Crops grown in rye-covered plots and fertilized at high levels of N will usually yield less than plots fertilized with the same level of N but grown in bare soil. However, the difference between the yields from the bare soil and those from the rye-covered plots at the high rates of N will not be as great as the difference in yields between the bare soil and rye-covered plots at the low rates of N.

Hairy vetch was included in the first studies but not in later studies. Hairy vetch planted in the fall at WWAREC germinated well, and some growth occurred during late fall and early winter. However, growth was minimal in relation to rye. Neither cover crop grew well during the early and mid-winter months, but rye resumed growth and grew well in late February and early March. In contrast, hairy vetch did not grow substantially until April. The average frost-free date at WWAREC is April 15, with cabbage normally being planted prior to this date and corn and tomatoes planted shortly after this date. When hairy vetch is killed prior to this date, little biomass has been produced.

Not only is there little biomass produced prior to the average frost-free date, but hairy vetch is difficult to kill with glyphosate. Although growth suppression was obtained from the herbicide, regrowth normally occurred within three weeks of the herbicide application, and vigorous growth occurred shortly thereafter. By the middle of the growing season, vetch was often a significant weed species. Vetch planted in the spring grew minimally during the summer and, even after being sprayed with glyphosate, grew vigorously and competed with the broccoli during the fall. Because of these problems, hairy vetch was not included in the later studies.

Broccoli

Both crops of broccoli were grown in the fall. The yield of broccoli in 1988 was lower in the vetch-covered plots than in either the bare soil or rye-covered plots (Table 1). In 1989 the lowest yield was in the ryecovered plots. In both years, the highest yield was in the bare soil plots. Insect damage to the broccoli was minimal, and no significant differences were seen among cover crop treatments.

Cabbage

In 1989 the yield from the rye-covered plots was lower than the yield from either the bare soil plots or the vetch-covered plots. In 1990 the yield from the rye-covered plots was lower than the yield from the bare soil plots. In 1989 cabbage loopers *(Trichoplusia ni)*, thrips (>90% *Frankliniella fusca)* and turnip aphids *(Hyadaphis erysimi)* were the major pests observed on cabbage. Populations of cabbage loopers, thrips and aphids were significantly lower on cabbage grown in rye-covered plots than in bare soil or vetch-covered plots. In 1990 few aphids were observed, and thrips populations were substantially lower than observed in 1989. As a result of lower populations, no significant effects of soil cover on thrips or aphid populations were observed. Diamondback moths *(Plutella xylostella)* were present as pests in 1990 but did not occur in large numbers and appear not to be affected by ground cover. However, fewer cabbage looper eggs and larvae were observed on rye-covered plots than on bare soil plots. Generally, it appears that cabbage grown in rye tends to have fewer insect pest numbers and reduced amounts of damage.

Populations of cabbage looper and aphids were positively related to increasing N levels in 1989. In 1990 a strong relationship between N levels and damage caused by cabbage looper was observed. The percentage of marketable heads declined with increasing N rates as a direct result of increased amounts of damage by lepidopterous larvae.

Sweet Corn

In 1989 the marketable yield was lowest in the rye-covered plots. In 1990 the same trend was noted, although the differences were not statistically significant. Most insect damage was caused by the corn earworm *(Heliothis zea)*. Although populations of corn earworm and the resulting damage to ears were high in 1989 and 1990, significant effects of ground covers were not observed. It appears that oviposition by earworm moths is not affected by ground covers.

Table 2. Tomato damage by stink bug and fruitworm for two years as affected by soil covers.

	Stink Bug		Fruitworm	
Soil Covers	1989[1]	1990[2]	1989[2]	1990[2]
Bare Soil	3.3b[3]	15.4b	9.5ab	19.4a
Rye	3.8a	33.6a	6.4b	10.9b
Vetch	3.4b	...	10.1a	...

[1]1-5 rating: 1=no damage, 5=severe damage
[2]Percentage of culls caused by stink bug or fruitworm
[3]Means separation by Duncan MRT (P = 0.05). Means followed by the same letter within the same year and crop are not significantly different.

Tomatoes

Marketable yield of tomatoes was lower in the rye-covered plots than in the bare soil plots in 1990 (Table 1). In 1989 the same trend was noted, although the differences were not statistically significant. Two insect groups caused the majority of pest damage in our studies: stink bugs (green stink bug *[Acrosternum hilare]* and brown stink bug *[Euschistus servus]);* and tomato fruitworm *[Helicoverpa zeal.* Damage by stink bugs was extremely heavy in 1989. In 1990 there was less stinkbug damage but more fruitworm damage. The effects of ground cover were consistent in both years. Tomato fruitworm damage was lower on tomatoes grown in rye plots, and damage by stink bugs was greater in rye-covered tomato plots compared with bare ground tomato plots (Table 2).

DISCUSSION

All of the experiments described above were conducted for one growing season in a particular field. One explanation for the reduced yield of the crops

Table 1: Yield of broccoli, cabbage, sweet corn and tomatoes In metric tons per hectare as affected by soil covers during two years.

	Broccoli		Cabbage		Corn		Tomato	
Soil Covers	1988	1989	1989	1990	1989	1990	1989	1990
Bare Soil	8.6a[1]	8.1a	24.9a	15.4a	12.5a	8.6a	37.1a	46.5a
Rye	7.8a	6.9b	20.1b	8.8b	9.1b	6.2a	35.3a	33.1b
Vetch	6.3b	7.9a	23.9a	...	13.08	...	38.2a	...

[1]Means separation by Duncan MRT (P = 0.05). Means followed by the same letter within the same year and crop are not significantly different.

grown in rye was that a N deficiency was caused by N immobilization by the rye. If this was the case, then the N content of the soil should be increasing with time. If the same cropping system is used for several seasons, the immobilized N in the soil should eventually reach an equilibrium with the plant-available N in the soil. At this time, there should not be a further reduction in yield with cash crops grown in the rye-covered plots.

Weed control is a major concern when cash crops are planted into cover crop residues. Mechanical cultivation techniques such as plowing and hoeing do not work well because the machinery used in such operations has been developed for bare soil conditions. Cover crop residues on the soil surface interfere with the tillage operation and prevent the development of a finely tilled soil surface. In addition, the concept of mechanical cultivation is contrary to the objectives of cover crop-conservation tillage techniques, since the cultivated soil is now subject to erosion.

Herbicides have been used extensively in many crops for weed control. However, most herbicides were developed for a clean cultivation production system and may not perform adequately when the soil contains cover crop residues. The effectiveness of these herbicides may be greatly reduced if they come in contact with soil organic matter or cover crop residues. Weed control was less effective with no-till than with conventional till when snap beans were grown in Tennessee (Mullins et al., 1988). In addition, there is now an emphasis on the development of farming systems that minimize the use of all pesticides, including herbicides. Because of these restrictions, it is imperative that an alternative method of weed control be developed.

Plant allelopathy is a factor that needs to be further explored relative to weed control in cover crop systems. Rye is known to be allelopathic (Chou and Patrick, 1976), but allelopathy as a method of weed control has never been fully explored (Altieri and Doll, 1978; Minotti and Sweet, 1981; Rice, 1974). Patrick and Toussoun (1965) found that certain cereal residues were allelopathic to plant germination and seedling growth. They stated that the phytotoxic effect was greatest from 10 to 25 days after residue incorporation, with little or no activity after 60 days. Barnes and Putnam (1986) found in a greenhouse simulation that rye residues reduced emergence of lettuce and millet. Worsham (1984) stated that rye used in a no-till situation could reduce weeds grown during the next season, but the effect on growth of the cash crop was inconclusive.

Allelopathy could also explain why cash crops grown in rye-covered plots yielded less than the same crops in bare soil. It is probable that a combination of reasons, including N immobilization, allelopathy and competition from weeds, lowered the crop yields. Farming systems are needed that will maximize farmer profit while minimizing damage to the environment. An ideal system would eliminate soil erosion, allow the growth of the cash crop, and suppress weed growth. At present, no such system has been designed. Work is now underway at WWAREC to examine the allelopathic effects of rye as an herbicide or as a weed suppressant.

SUMMARY

The results from two years of data with four crops indicate that marketable yields from crops grown in rye-covered plots will usually be lower than yields from bare soil plots. Increased applications of N may partially offset, but not totally eliminate, this decrease in yield. Hairy vetch grows more slowly than does rye and is more difficult to kill with glyphosate than is rye. Although N fixation by vetch is advantageous, rye has been a better cover crop relative to soil cover and lessened soil erosion than has hairy vetch.

The response of insects to cover crops varies with the insect in question. The greatest change in pest populations as a result of altering ground covers was observed on cabbage, especially with cabbage looper. On tomatoes, rye covers decrease tomato fruitworm damage but result in greater damage by stink bugs. Corn earworm on sweet corn does not appear to be significantly affected by ground covers. In general there were fewer insects and less insect damage in rye-covered plots. Nitrogen fertilization appears to have its greatest effect on cabbage looper and aphid populations on cabbage. Pest populations and damage on sweet corn and tomatoes appear not to be significantly affected by changes in N fertilization.

LITERATURE CITED

1. Altieri, M.A., and J.D. Doll. 1979. The potential of allelopathy as a tool for weed management in crop fields. PANS 24(4):495-502.

2. Barnes, J.P., and A.R. Putnam. 1986. Evidence for allelopathy by residues and aqueous extracts of rye *(Secale cereale)*. Weed Science. 34:384390.

3. Chou, Chang-Hung, and Z.A. Patrick. 1976. Identification and phytotoxic activity of compounds produced during decomposition of corn and rye residues in soil. J. Chem. Ecol. 2:369-387.

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

5. Lockeretz, William, Georgia Shearer, Daniel H. Kohl and Robert W. Klepper. 1984. Comparison of organic and conventional farming in the Corn Belt. p. 37-48. *In* Organic farming: Current technology and its role in a sustainable agriculture. Madison WI: ASA, CSSA, SSSA.

6. Minotti, P.L., and RD. Sweet. 1981. Role of crop competition in limiting losses from weeds. p. 351-367. *In* D. Pimentel (ed). CRC Handbook of pest management in agriculture. Vol 2. Boca Raton, Florida: CRC Press, Inc

7. Morse, Ronald D., and David L. Seward 1986. No-tillage production of broccoli and cabbage. Applied Agricultural Research 1(2):96-99.

8. Morse, RD., C.M. Tessore, W.E. Chappell and C.R. O'Dell. 1982. Use of no-tillage for summer vegetable production. The Vegetable Growers News 37(1):1.

9. Mullins, Charles A., R Allen Straw and David L. Coffey. 1988. Production of snap beans as affected by soil tillage method and row spacing. J. Amer. Soc. Hort., Sci 113(5):667-669.

10. Nelson, W.A., B.A. Kahn and B.W. Roberts. 1991. Screening cover crops for use in conservation tillage systems for vegetables following spring plowing. HortScience (in press).

11. Papendick, RI., and L.F. Elliott. 1984. Tillage and cropping systems for erosion control and efficient nutrient utilization. p. 69-81. *In* Organic farming: Current technology and its role in a sustainable agriculture. Madison WI: ASA, CSSA, SSSA.

12. Patrick, Z.A., and T.A. Toussoun. 1965. Plant residues and organic amendments in relation to biological control p. 440-459. *In* K E Baker and W.C. Synder (eds.). Ecology of soil-borne pathogens. Berkeley, Calif: Univ. of California

13. Phillips, RE., RL. Blevins, G.W. Thomas, W.W. Frye and S.H. Phillips. 1980. No-tillage agriculture. Science. 208 1108-1113.

14. Rice, E.L. 1974. Allelopathy. New York Academic Press, Inc

15. Worsham, AD. 1984. Crop residues kill weeds: Allelopathy at work with wheat and rye. Crops and Soils Magazine. Nov. 1984. p. 18-20.

16. Zehnder, G.W., and J.J. Linduska 1987. Influence of conservation tillage practices on populations of Colorado potato beetle (Coleoptera: Chrysomelidae) in rotated and non-rotated tomato fields. Environ. Entomol. 16:135-139.