Effect of Winter Cover Crops and No-Till on the Yield of Organically-Grown Bell Pepper (*Capsicum annuum* L.)

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Abstract

There is limited information on the utilization of no-till methods in organic vegetable production. The objective of this study was to determine the effects of cover crop and no-till on weed control and yield of bell pepper. The experimental design was a split plot with four replications, where tillage (conventional tillage or no-till) was the main plot and cover crop (rye, rye/crimson clover, or barley/crimson clover) the subplot. The seasonal mean soil moisture content was higher under no-till compared to conventional tillage, and was unaffected by the type of cover crop. There were no differences in the amount of biomass produced by the cover crops among cover crop or tillage treatments. Weed density was high in most of the plots, particularly in the no-till plots. Weed control over the season determined visually was 84% and 27% for the conventional tillage and no-till, respectively. Insect pests and diseases were not major factors affecting plant growth or fruit yield. Marketable and total cumulative yields were higher under conventional tillage compared to no-till, while there were no yield differences among the various cover crops. High weed pressures under no-till likely contributed to the reduced yields.

INTRODUCTION

Weeds are a major factor limiting organic vegetable production. Many US organic growers rate weeds as the number one factor affecting vegetable yields (Waltz, 1999). By competing with the crop for water, light and nutrients, weeds affect the growth and yield of vegetable crops, and this competition may result in a complete yield loss if weeds are not controlled on time. The most common methods of organic weed control include mechanical cultivation, utilization of organic mulches (e.g., wheat straw) or plastic film mulches, and manual weeding (Bond and Grundy, 2001). Application of organic mulches and manual weeding are expensive methods of weed control. There are limited studies on the use of cover crops and no-till production methods in organic or sustainable vegetable production (Abdul-Baki and Teasdale, 1993; Morse, 1999; Papendick and Parr, 1997; Snapp et al., 2005; Teasdale et al., 1991). Cover crops are useful in the management of weeds, insects and pathogens and provide several benefits to soil quality (Fageria et al., 2005; Phatak and Díaz-Pérez, 2007; Teasdale, 1996). Cover crop residues on the soil surface reduce soil water evaporation and provide organic matter to the soil, resulting in increased soil water-holding capacity. The objective of this study was to determine the effects of winter cover crops and no-till production on weed control and yield of organic bell pepper.

MATERIALS AND METHODS

The trial was conducted during the spring of 2005. The experiment was a split plot with four replications, where tillage (conventional or no-till) was the main plot and cover crop the subplot. The cover crop treatments were rye (*Secale cereale*) alone, rye/crimson clover (*Trifolium incarnatum*), and barley (*Hordeum vulgare*)/crimson clover. Cover crops were planted in November of 2004 and killed by flail-mowing when plants were at the flowering stage (three weeks before the planting of peppers). The experimental plot consisted of an 18-m long, flat bed formed on 1.8-m centers.

The experimental area received a total of 6.7 $t{\cdot}ha^{-1}$ of an organic fertilizer based on chicken manure (4N: $2P_2O_5$: $3K_2O$; MicroSTART 60, Perdue AgriRecycle, LLC, Delmarva, Delaware, US) one week prior to planting the pepper plants. On May 4, six-week old pepper ('Stiletto') transplants were planted in a double row per bed (36 cm between rows) at 30 cm spacing between plants within the row. At transplanting, each plant received about 250 ml of a solution containing fish emulsion fertilizer (5-1-1; N, P_2O_5, and K_2O, respectively, Alaska Liquid Fish Fertilizer). Four weeks after transplanting, plants were fertilized with 560 $kg{\cdot}ha^{-1}$ feather meal (13 N: 0 P_2O_5: 0 K_2O) and 210 $kg{\cdot}ha^{-1}$ sodium nitrate (16 N:0 P_2O_5 :0 K_2O).

The crop was irrigated with an overhead sprinkling system, with an average of 25 mm water applied at each irrigation event. Irrigation was based on cumulative evapotranspiration data from a local (within 300 m) University of Georgia weather station and the crop coefficient for bell pepper (0.3 at early stage, 0.7 at midseason, 1.0 for developed plants). Soil moisture content was measured with a time-domain reflectometry sensor (CS620 Water Content Sensor, Campbell Scientific Inc., Logan, Utah) containing two 12-cm long probes, which were inserted vertically into the soil, half way between two plants within a row. No pesticides were applied to the pepper plants. Soil samples (top 8 cm) were taken at the end of the pepper growing season to determine soil organic matter and organic active carbon. Soil organic matter was determined by the "loss on ignition" method for 3h at 360°C. Soil organic active carbon was determined by the Soil Quality Research Lab, University of Maryland, US.

Weed control among tillage treatments was estimated visually as the percent of the total crop soil area that was free of weeds. Percent weed control was estimated before weeds were removed. Weeds were removed by mechanical cultivation (conventional tillage) 22, 33, and 48 days after planting, and manually (all plots) 30, 37, 44, and 49 days after planting. A three-member weeding crew removed the weeds and the cumulative times required to do so were recorded. Prior to the first harvest, four randomly-selected plants (top plus roots) from each replication were removed from the soil. Plant tops and roots were dried at 70°C and their dry weights (DW) were determined. Pepper plants were harvested manually on 15 July (74 DAP), 21 July (80 DAP) and 29 July (88 DAP). Fruit were graded as marketable or culls (fruit with rots, insect damage, or mechanical injury), based on the US grading standards for bell pepper and yields per hectare were calculated. After the last harvest, a composite soil sample (10 cm deep) from each plot was collected and analyzed for pH, organic matter, Ca, K, Mg, Mn, P, and Zn by the Soil, Plant, and Water Laboratory (University of Georgia, Athens, Georgia, US). Data were analyzed using the General Linear Model of SAS (SAS OnlineDoc Version 8, SAS Institute Inc., Cary, NC).

RESULTS AND DISCUSSION

There was no tillage x cover crop interaction for any of the factors. In both tillage treatments, soil moisture tended to decline over the season and the seasonal mean of soil moisture was higher ($P<0.05$) under no-till (9.9%) compared to conventional tillage (9.4%). Soil moisture was unaffected by the type of cover crop. The increased soil moisture under no-till conditions was consistent with other studies.

There were no differences in the amount of biomass produced by the cover crops. Soil organic matter (top 8 cm; mean = 1.26%) and the active carbon concentration (mean = 127 mg active C/kg soil) in the soil were similar among cover crops and among tillage treatments. Our results differ from previous studies that show that tillage is associated with reduction in organic matter content in the soil. The lack of additional carbon accumulation in the no-till plots in this study may have been attributable to tillage during the previous year to control the high population of weeds that developed in the preceding squash crop.

There was no regrowth of the cover crop plants after flail mowing due to high temperatures that resulted in the mortality of cover crop plants. Weeds were removed manually from the plots on four occasions during the pepper growing season. The no-till plots and the conventional tillage plots required 361 and 246 man-hours per hectare, respectively, to control weeds. High temperature and high soil moisture conditions encouraged rapid weed growth, which made the hand-weeding difficult. Weed density was high in most of the plots, particularly in the no-till plots. Grasses (species were not identified) followed by nutgrass (*Cyperus rotundus*) were the predominant weeds in the conventional plots, while broadleaf weeds (species were not identified) followed by grasses and nutgrass were the predominant weeds in the no-till plots. Nutgrass was more common in the conventional tillage than in the no-till plots. Grass weeds tended to be the most difficult to remove, as their fibrous root systems intertwining with the pepper crop made hand removal difficult. Mean weed control over the season determined visually was 84% and 27% for the conventional tillage and no-till, respectively. The reduced weed density in the conventional plots was due to the contribution of mechanical cultivation. Among cover crops, weed control was highest on rye/crimson clover (62%), followed by barley/crimson clover (55%) and rye alone (50%). Rye residues were visually more persistent in the field than barley residues. Our results are consistent with previous studies that show that cover crops provide limited weed control. The high weed density under no-till was a major factor in reducing pepper plant growth. Other factors which may have influenced pepper crop growth, e.g., soil fertility and carbon:nitrogen ratio, were not assessed in this trial.

Top and root biomass and root-to-shoot ratio were higher in conventional tillage compared to no-till (Table 1). The increased weed populations in no-till plots was probably an important factor in reducing pepper plant growth because weeds compete with crops for nutrients, water and light. It is also possible that the decomposition of cover crop residues resulted in some soil nitrogen being tied up, reducing the nitrogen available to the pepper crop (Coolman and Hoyt, 1993; Johnson and Hoyt, 1999). There were no differences in pepper plant top and root growth among cover crops.

Insect pests and diseases were not major factors affecting plant growth. No significant differences were observed in insect populations among treatments, either for pest or beneficial species (data not shown). Few pest insects were present on the pepper plants in the trial throughout the growing season, and they caused little damage. The numbers and diversity of beneficial, ground-dwelling insects trapped in pitfall traps placed within the plots did not vary among treatments. The lack of differences among treatments for pitfall trap samples likely reflects the difficulty in managing weeds in plots.

Yields declined as the season progressed, probably as a result of the high temperatures during the summer. Marketable and total cumulative yields were higher under conventional tillage compared to no-till, while there were no yield differences among the various cover crops (Table 2). In a recent study (unpublished data), we found that in no-till plots mulched with either plastic film mulch or wheat straw mulch yields of broccoli were higher and there were fewer weeds compared to no-till plots with no plastic film mulch or wheat straw mulch. In this study, we did not find differences in leaf chlorophyll content between tillage treatments or among cover crop treatments, which suggested that there were no differences in soil N availability associated with treatments. Additionally, soil analysis of samples taken after the last pepper harvest showed that there were no significant differences in pH (mean = 6.52), organic matter (mean = 1.26%), Ca (mean = 1244 $kg \cdot ha^{-1}$), K (mean = 146 $kg \cdot ha^{-1}$), Mg (mean = 154 $kg \cdot ha^{-1}$), Mn (mean = 21 $kg \cdot ha^{-1}$), P (mean = 185 $kg \cdot ha^{-1}$), and Zn (mean = 16 $kg \cdot ha^{-1}$) among tillage or cover crop treatments. Thus, high weed pressures under no-till conditions were probably the primary cause for the reduced yields. Weeds compete with the crop for nutrients, water and light, resulting in reduced crop growth and yield. This study, however, was not designed to determine the way weeds affect pepper yield under no-till conditions. Our data showed no differences in soil nutrition (after harvest) among treatments, although it is possible that weeds may have reduced nutrient availability in the root zone of the pepper crop during the growing season.

Mean fruit size was higher under conventional tillage compared to no-till and it was unaffected by cover crop treatment. From the total harvested fruit, marketable fruits represented 42% and 25% for conventional and no-till, respectively. Fruit decay, resulting from fruit being in direct contact with the soil, was a major factor affecting fruit quality. Sunscald, exacerbated by the limited foliar development of bell pepper plants, also affected fruit quality.

In conclusion, high weed pressures under no-till conditions were probably the primary cause for the reduced plant growth and fruit yields in organically-grown bell pepper. Thus, in addition to the utilization of cover crops, other methods of weed control may be necessary in organic no-till vegetable systems.

ACKNOWLEDGEMENTS

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Tables

Table 1. Growth of bell pepper plants as affected by tillage and cover crop. Grown in the spring of 2005 in Tifton, Georgia.

	Top FW (g)	Root FW (g)	Top DW (g)	Root DW (g)	Root-to-top ratio
Tillage					
Conventional	545 a[z]	30.9 a	54.2 a	8.4 a	0.22 a
No-till	239 b	25.4 b	32.3 b	6.8 b	0.17 b
Cover crop					
Rye	376 a	29.0 a	42.9 a	7.8 a	0.20 a
Barley/clover	388 a	29.0 a	43.2 a	8.0 a	0.20 a
Rye/clover	411 a	26.6 a	43.7 a	7.0 a	0.19 a
Significance					
Tillage	<0.01	0.016	<0.01	<0.01	0.02
Cover crop	0.735	0.626	0.976	0.379	0.791

[z] Means separated within column groups by Fisher's protected LSD test ($P \leq 0.05$).

Table 2. Yield of bell pepper as affected by tillage and cover crop. Grown in the spring of 2005 in Tifton, Georgia.

Treatment	Marketable fruit		Total fruit		Ave. fruit weight
	no./ha	$kg \cdot ha^{-1}$	no./ha	$kg \cdot ha^{-1}$	(g)
Tillage					
Conventional	39,559 a[z]	4,896 a	95,112 a	8,399 a	124 a
No-till	13,475 b	1,399 b	53,432 b	3,390 b	104 b
Cover crop					
Rye	20,706 a	2,458 a	66,589 a	4,840 a	118 a
Barley/clover	29,814 a	3,548 a	83,769 a	6,685 a	119 a
Rye/clover	29,030 a	3,436 a	72,459 a	5,978 a	119 a
Significance					
Tillage	<0.01	<0.01	<0.01	<0.01	<0.01
Cover crop	0.334	0.378	0.520	0.346	0.273

[z] Means separated within column groups by Fisher's protected LSD test ($P \leq 0.05$).