Tillage System and Cover Crop Management Impacts on Soil Quality and Vegetable Crop Performance in Organically Managed Production in Tennessee

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Abstract. Research is lacking on the impact of alternative reduced tillage (RT) systems on vegetable crop performance and soil quality, especially in organic production systems, where weed control cannot rely on synthetic herbicides. A 2-year field study was implemented in Aug. 2010 in Knoxville, TN, to evaluate cover crop–based systems for organic vegetable production either with or without spring tillage. Treatments, all organically managed, included 1) Till (+ACC), spring tillage of a winter cover crop with aboveground cover crop biomass (ACC) retained and soil covered by polyethylene mulch; 2) Till (−ACC), spring tillage of a winter cover crop with aboveground cover crop biomass (ACC) removed before tillage and soil covered by polyethylene mulch; and 3) RT system with no spring tillage and mechanically terminated winter cover crop residue on the soil surface. Vegetable crops of eggplant (Solanum melongena L.) and watermelon (Citrullus lanatus (Thunb.) Matsum. et Nakai) were planted in 2011 and 2012, respectively. Crop yield, cover crop biomass accumulation, soil N and C dynamics, and weed density were assessed. Marketable eggplant yield and marketable watermelon yield did not differ among treatments, but weed density was higher in the RT system. Measures of soil quality after 2 years of the study indicated that particulate organic matter reduced tillage (RM), and crop residue (POM-N) were highest in the RT treatment, a significant increase as compared with values at the beginning of the study. As a measure of the active fraction of soil organic matter, this indicates that the RT system may best maintain and improve soil quality in similar regional organic vegetable cropping systems. As indicated by measures of soil quality and crop yield, removal of aboveground cover crop biomass did not negatively impact the Till (−ACC) system as compared with the Till (+ACC).

In the southeastern United States as in many parts of the world, a large percentage of modern commercial vegetable production relies on the use of raised-bed, plasticulture production systems, especially for warm-season crops (Lamont, 1996; Orzolek, 1996). Although these systems can improve vegetable crop yields and quality, the system is also resource and capital-intensive, requiring substantial soil disturbance and tillage. Intensive tillage systems for continuous vegetable production can have a negative impact on chemical, physical, and biological measures of soil quality (Haynes and Tregoon, 1999). Increasing organic matter inputs through crop residue conservation (Lal, 1995), cover crops (Snapp et al., 2005), and manures or composts (Bulluck et al., 2002; Evanylo et al., 2008) can partially mitigate the negative impacts of tillage in these systems. Further improvement in soil quality may be possible through reduction in the number of tillage and cultivation events by implementation of cover crop–based RT production systems (Carr et al., 2013; Gadermaier et al., 2011; Lewis et al., 2011), but these systems have been far less widely adapted and researched in vegetable production than in field crop and grain production (Morse, 1999; Price and Norsworthy, 2013).

In RT cover crop–based production systems, annual cover crop species are planted and mature during off-season periods of the year, and are then ended before cash crop planting (Reberg-Horton et al., 2012). In conventional systems, cover crops are often ended with the aid of herbicides, but due to prohibition of synthetic herbicides in organic systems and the limited availability and economic feasibility of herbicides accepted by organic certification frameworks, cover crops in these systems are typically ended mechanically (e.g., roller-crimper or similar equipment) at later stages of physiological maturity (Ashford and Reeves, 2003; Creamer and Dabney, 2002; Mirsy et al., 2009; Reberg-Horton et al., 2012). Mechanical termination at these growth stages (typically, late flowering for legume species and postanthesis for small grains) leaves a surface mulch that can help suppress weeds, maintain soil moisture, and improve crop quality. However, it can also hamper cultivation for weed management, slow soil warming and nutrient mineralization, and potentially increase disease and pest pressure (Ashford and Reeves, 2003; Leavitt et al., 2011; Price and Norsworthy, 2013; Reberg-Horton et al., 2012). Cover crop species selection in organic systems is also complicated compared with conventional systems by the lack of synthetically derived N fertilizer for subsequent vegetable crop production, making cover crop impacts on soil N availability a vital consideration (Reberg-Horton et al., 2012).

In humid and subtropical regions such as the southeastern United States, there is a body of recent applied research evaluating crop productivity and weed control in these systems for both conventional (Abdul-Baki et al., 1996a, 1996b, 1997a, 1997b, 1999, 2002; Masiunas et al., 1995; Morse, 1995; Rutledge, 1999; Teasdale and Abdul-Baki, 1997, 1998) and organic (Mulvaney et al., 2011; Teasdale et al., 2008; Vollmer et al., 2010) vegetable production. At the same time, there is minimal information on the relative impact of these organic RT systems on soil quality compared with similar systems with more extensive tillage use. In mixed crop-livestock production systems, cover crops may also serve as forage crops through either mechanical harvest or grazing, while still providing agronomic benefits to cash crops in rotation and soil quality benefits (Franzluebbers and Stumbo, 2014), but this has not been well explored, especially for vegetable cropping systems. Given the paucity of information relating to crop performance and soil quality dynamics in RT organic production systems, information on these systems is needed to facilitate adoption across diverse environments and soil types. To meet this need, the objectives of the present study were to evaluate 1) vegetable crop performance in organically managed cover crop–based RT production systems in comparison with tilled, plasticulture systems with aboveground cover crop biomass either retained or removed and 2) soil quality dynamics associated with these production systems during a 2-year study period.

Materials and Methods
Site description and establishment. The study was conducted at the University of Tennessee Organic Crops Unit near Knoxville,
TN (35.88°N, 83.93°W). Establishment occurred in Aug. 2010 and the soil at the research site is a fine, kaolinitic, thermic Typic Paleudult (USDA-NRCS classification), with a clay loam surface texture (30% sand, 41% silt, 29% clay) and an initial soil pH of 6.9. The climate is humid subtropical with annual rainfall averaging 153 cm and mean annual temperature averaging 14 °C, with a January average of 3 °C and a July average of 25 °C. During the years of the study, annual temperatures at the site averaged 14 °C in 2010, 15 °C in 2011, and 17 °C in 2012. Precipitation at the site was below average in all years of the study, with 104 cm in 2010, 138 cm in 2011, and 106 cm in 2012 (data not shown). Additional weather data from the Organic Crops Unit from 2010 to 2012 is presented in Eicher Inwood et al. (2015). Conventional fertilizer, herbicides, and treated seeds had not been applied to the field containing the study site since Mar. 2008. The site was planted to wheat (Triticum aestivum L.) in Autumn 2007, rye (Secale cereale L.) in Autumn 2008, soybean [Glycine max (L.) Merr.] in Spring 2009, and fallow (mowed for weed management) in 2010 before the start of the study.

The study was established as a randomized complete block design with four replicates. Three vegetable production treatments were randomly assigned to plots (each 2.4 m by 9.1 m) in each block. Management system treatments were as follows: 1) Till (+ACC), spring tillage of a winter cover crop with aboveground cover crop biomass (ACC) retained and soil covered by polyethylene mulch; 2) Till (~ACC), spring tillage of a winter cover crop with aboveground cover crop biomass (ACC) removed before tillage and soil covered by polyethylene mulch; and 3) RT, RT system with no spring tillage and mechanically terminated winter cover crop residue on the soil surface (Table 1). Treatments were applied to the same locations in each year.

Production system management. To begin the study and end existing weeds on site, the field area was plowed (moldboard), disked (offset double disk), and harrowed (spring tine with rolling basket). On 14 Sep. 2010, broiler litter was applied in Sept. 2011 at half the recommendation (28% moisture content; 0.88 Mg C/ha, 125 kg total N/ha, 56 kg P/ha, 51 kg K/ha) and incorporated. All plots were tilled with the rotary tiller at the time of broiler litter incorporation to facilitate cover crop establishment and standardize fall tillage among systems. In RT or rotational no till systems, this once annual tillage event serves to end perennial weeds, incorporate any remaining residues, incorporate fertility amendments, and create improved conditions for cover crop establishment (Mirskey et al., 2013). Broiler litter rates were calculated to approximate agronomic recommendations for the vegetable crops based on initial soil test P values (11.6 mg Mehlich 1 P/kg soil; Mehlich, 1953).

Cover crops were broadcast seeded on all treatments on 5 Oct. 2010 and 7 Oct. 2011, and then rolled to establish soil to seed contact. Plot were planted with a mixture of soft red winter wheat [cv. Haas Cover (2010) and cv. ForageMax (2011), 168 kg ha⁻¹] and crimson clover (Trifolium incarnatum L. cv. Dixie, 11 kg ha⁻¹). Cover crops in Till (+ACC) were ended at flowering (wheat = late boot stage) with a flail mower (SH74; Alamo Industrial, Seguin, TX, 5 May 2011) and then incorporated using a rotary tiller and a bed formed (0.9-m width) in the center of the plot, a drip irrigation line applied (5.6 L min⁻¹ flow rate per 100 m; T-Tape, John Deere/ T-Systems, San Diego, CA) and covered with black polyethylene mulch (0.032-mm embossed; Pliant-Berry Plastics, Evansville, IN). Till (~ACC) plots were similarly treated, with the exception that all aboveground cover crop biomass was harvested to a 7.5-cm stubble height and removed. RT cover crops were ended by rolling using the disengaged flail mower which has a roller and will flatten cover crops (Morse, 1999) at cover crop flowering (5 May 2011 and 20 Apr. 2012).

Eggplant (Solanum melongena L. cv. Traviata) transplants were produced in the greenhouse in 128-cell (36-cm³ cell volume) trays (Speedling Inc., Sun City, FL) with an organic seedling media (Premium Lite Growing Mix, McEnroe Organic Farm, Millerton, New York, NY). Transplants were planted in all plots on 11 May 2011, in a single 9.1-m row in the center of each bed and 45-cm spacing between plants. Transplants were planted by hand into polyethylene-mulched treatments after punching a small hole in the mulch. In RT treatments, transplants were planted by hand following pulling a coulter and shank through the soil to create a narrow furrow with minimal cover crop residue disturbance. To conform to crop rotation practices for organic production systems, watermelon (Citrullus lanatus (Thunb.) Matsum. et Nakai cv. Crimson Sweet) was produced during the 2012 season. Watermelon transplants were produced as described for eggplant and planted on 25 Apr. 2012 as described for eggplant except for 76-cm spacing between plants (in new plastic mulch, as applicable to treatment). To manage anthropods pests, all treatments used organically approved methods (dusting with diatomaceous earth and physical exclusion with spunbonded polypropylene rowcover in early crop growth stages). Aboveground vegetable crop residues were removed at the end of each season.

Cover crop biomass, crop performance, and weed evaluation. Before cover crop incorporation, a sample of aboveground biomass was collected from a 0.09-m² area (30 × 30 cm). Samples were then oven-dried (65 °C for at least 48 h), weighed, and ground. Total C and N (and C:N ratio) of cover crop tissue (by species) was determined by combustion (Flash EA 1112 NC Soil Analyzer; Thermo Fisher Scientific Inc., Waltham, MA). Eggplant fruit were harvested 6, 19, and 26 July and 2, 9, 16, and 23 Aug. 2011 from a 5.4-m length of bed and watermelon fruit were harvested 6, 12, 20, and 25 July 2012 from a 7.6-m length of bed. Fruit were graded according to U.S. Department of Agriculture standards (USDA-AMS, 2006, 2013) into marketable (i.e., Fancy, U.S. No. 1 and U.S. No. 2) and nonmarketable categories, then counted and weighed. Harvest data were extrapolated by assuming 5467 m of row per ha on a commercial basis. In the week before first harvest, recently matured leaves were collected from each plot, oven-dried (65 °C for at least 48 h), and total N determined by combustion as described for cover crop tissue samples. Weed density was assessed in each plot at 1 month following crop planting (7 June 2011, 30 May 2012). In polyethylene-mulched treatments, all weeds emerging through planting holes were counted. In RT, weeds were counted in a random 0.25-m² area (50 × 50 cm) within the crop row/bed (i.e., the plot area correlating to the polyethylene-mulched area in tilled treatments) in each plot. Weeds were removed by hand weeding following assessments.

Soil sampling and analysis. Soil cores (0 to 15 cm depth; 1.75-cm internal diameter) were collected from each plot before litter application at the beginning of the study (14 Sept. 2010), and on 16 May, 14 July, and 29 Aug. 2011 and 15 May, 23 July, and 27 Aug. 2012. Soil cores from each plot were composited, air-dried, and then sieved (<2 mm). Soil ammonium-N (NH₄-N) and nitrate-N + nitrite-N ([NO₃-N + NO₂-N]) were assayed as described by Sims et al. (1995) and Sims (2006). Briefly, ~5 g soil was extracted in 40 mL of 1 M KCl for 60 min on a reciprocating

Table 1. Management system treatment factors.

| Cover crop species | Cover crop termination | Fall tillage | Spring tillage | Mulch |
|--------------------|------------------------|-------------|---------------|-------|
| Till (+ACC)        | Common wheat + crimson clover | Flail mowed and incorporated | Rotary tiller | Polyeylethene |
| Till (~ACC)        | Common wheat + crimson clover | Cut and removed | Rotary tiller | Polyeylethene |
| RT                 | Common wheat + crimson clover | Roll-killad | Rotary tiller | Cover crop residue |

*Till = organic management with spring tillage; ACC = aboveground cover crop biomass; RT = reduced tillage organic management with no spring tillage.*
shaker, centrifuged (5 min at 3500 rpm) and then the supernatant was filtered (Whatman 42; Whatman Ltd., Kent, UK). Concentration of inorganic N constituents in filtrate was determined using a microplate reduction technique and absorbance measured at 550 nm (Powerwave XS). Soil total N and C was determined by combustion as described for cover crop tissue samples.

Soil particulate organic matter N (POM-C) and C (POM-C) were measured using methods described by Marriott and Wander (2006). Briefly, 20 g of sieved, air-dried soil was weighed into a mesh-covered vial (53-μm mesh; Wildlife Supply Company, Yulee, FL), shaken with 5% sodium bexametaphosphate, then rinsed multiple times with deionized water until the rinse was clear. The retentate was dried (50°C) and weighed before homogenization in a ball mill (PowerGen; Thermo Fisher Scientific). Homogenized samples were analyzed for total N and total C content (i.e., POM-N and POM-C) by combustion as described previously for cover crop tissue. Soil permanganate oxidizable carbon (POx-C) was determined using methods described by Weil et al. (2003). In brief, soil was shaken with 0.02 M KMnO4 for 2 min and then centrifuged (5 min at 3000 rpm). Absorbance of a diluted aliquot of the supernatant was measured at 550 nm (Powerwave XS). Final concentrations of C and N constituents in soils were determined based on exact weights of extracted soil and extract concentrations.

**Statistical analysis.** Cover crop, soil quality, vegetable crop, and weed density data for each season were subject to mixed models analysis of variance (ANOVA) using PROC GLIMMIX in SAS software (version 9.4; SAS Institute Inc., Cary, NC) with management system, year, and the interaction of management system and year considered as fixed effects and block and the interaction of management system, year, and the interaction of management system and year considered as random effects. Weed data were log10 transformed to improve variance homogeneity and provide a more normal distribution of the data and soil inorganic N data were transformed and soil inorganic N data were average aboveground cover crop biomass was not at a level (>20:1) expected to induce substantial N immobilization (Table 2) (Quemada and Cabrera, 1995). It is possible that the incorporated aboveground cover crop biomass may have reduced soil temperature and/or altered soil moisture content or soil water potential compared with Till (–ACC) and thus led to slower N mineralization (Cassman and Munns, 1980). It is also possible that due to biochemical composition of residues in combination with the soil matrix, mineralization kinetics of aboveground and belowground residues was slower than that of belowground residues (including rhizodeposition and unharvested ecosystem effects) and that reported for mixtures of cereal rye and crimson clover in the region (Reberg-Horton et al., 2012). Total C in aboveground cover crop biomass averaged 4204 kg C/ha and total N averaged 216 kg N/ha, for a C:N ratio of 19:1. This ratio at less than 20:1 and would be expected to release N relatively quickly during decomposition (Whitmore, 1996). However, decomposition rates would likely be complicated by the advanced maturity of the residue (greater lignin, hemicellulose, and phenolic content) and, for the RT system, placement at the soil surface where biological decomposition would proceed more slowly (Ranells and Wagger, 1996; Reberg-Horton et al., 2012). Biomass of wheat averaged 64% (6.6 Mg ha–1; C:N ratio of 22:1) of total biomass and crimson clover 36% (3.7 Mg ha–1; C:N ratio of 15:1; Table 2). Biomass of nonsown species in cover crop biomass was minimal (<0.1 Mg ha–1).

**Vegetable crop weed density.** Weed density 1 month after transplanting was similar (P > 0.05) among treatments which used black polyethylene mulch [Till (±ACC)] in 2011, with an average of less than 5 weeds/m2 (Table 3). In 2012, weed density was slightly less in the Till (±ACC) (3.5 weeds/m2) than Till (–ACC) (8.4 weeds/m2; Table 3). Nutsedges (Cyperus sp.), which often occur in the practice, were not present on the site. The primary weed species observed included field bindweed (Convolvulus arvensis), large crabgrass (Digitaria sanguinalis), and carpetweed (Mollugo verticillata). Weed density was more than 10-fold higher in RT in each season. This difference is perhaps not surprising, given the small area of the transplanting hole available for weed growth in the polyeethylene-mulched Till treatments as compared with the RT treatment, but it does give an indication of relative differences in weed pressure among systems. Slightly lower weed density in the Till (±ACC) system as compared with Till (–ACC) may be a product of increased biological activity due to biomass incorporation which could potentially increase weed seed decomposition (Liebman and Davis, 2000). Weeds in RT could negatively impact yield when emerging during the critical weed free period, may interfere with harvest, and may complicate future phases of the crop rotation as compared with the lower weed density in the Till system. **Table 2.** Mean aboveground cover dry biomass, biomass total carbon (C), biomass total nitrogen, (N) and biomass C:N ratio in Spring 2011 and 2012.

| Biomass          | Total C     | Total N     | C:N ratio |
|------------------|-------------|-------------|-----------|
|                  | Mg·ha–¹     | kg·ha–¹     |           |
| Total biomass²   | 10.3 (8.2, 12.4) | 4204 (3341, 5067) | 216 (176, 256) | 19:1 (18:1, 20:1) |
| Wheat biomass    | 6.6 (4.3, 8.9) | 2688 (1740, 3636) | 120 (78, 162) | 22:1 (21:1, 23:1) |
| Crimson clover biomass | 3.7 (2.5, 4.9) | 1458 (978, 1938) | 93 (65, 121) | 15:1 (14:1, 16:1) |

²Includes biomass of weeds/nonsown species.
³95% confidence intervals of the mean.

**Results and Discussion**

**Cover crop biomass.** Average aboveground cover crop biomass at termination did not differ among management systems over 2 years (P > 0.05) and averaged 10.3 Mg·ha–¹ (Table 2). This level of biomass accumulation is above the 8 to 9 Mg·ha–¹ generally reported as needed for weed control in RT cover crop systems (Mirsky et al., 2013; Mohler and Teasdale, 1993; Reberg-Horton et al., 2012; Smith et al., 2011). Although no studies have specifically evaluated wheat and crimson clover bicultures, biomass observed in the present study is above the median of that reported for mixtures of cereal rye and crimson clover in the region (Reberg-Horton et al., 2012). Total C in aboveground cover crop biomass averaged 4204 kg C/ha and total N averaged 216 kg N/ha, for a C:N ratio of 19:1. This ratio at less than 20:1 and would be expected to release N relatively quickly during decomposition (Whitmore, 1996). However, decomposition rates would likely be complicated by the advanced maturity of the residue (greater lignin, hemicellulose, and phenolic content) and, for the RT system, placement at the soil surface where biological decomposition would proceed more slowly (Ranells and Wagger, 1996; Reberg-Horton et al., 2012). Biomass of wheat averaged 64% (6.6 Mg·ha–¹; C:N ratio of 22:1) of total biomass and crimson clover 36% (3.7 Mg·ha–¹; C:N ratio of 15:1; Table 2). Biomass of nonsown species in cover crop biomass was minimal (<0.1 Mg·ha–¹).
labile organic matter in several established authors reported no differences in POM-N at Georgia (Beare et al., 1994). However, the tilled soils following 13 years of management in 0 to 5-cm depth in no till vs. conventionally was similarly reported in southeastern U.S. POM-N/kg). Higher POM-N under no tillage that observed from the RT system (409 mg POM-N/kg soil) at the same research site, slightly higher than 2 years of perennial organic forage management average of 460 mg POM-N/kg following ison, Eichler Inwood et al. (2015) reported an 331 mg POM-N/kg soil] increase over 2 years N/kg soil, 95% CI (49 mg POM-N/kg soil, this represents an average 87% [190 mg POM- and the least in tilled systems (Fig. 1; 283 to soil in the RT system (Fig. 1). For the RT system, this represents an increase of 29% from 938 mg N/kg soil in Fall 2010, or 275 mg N/kg soil [95% confidence interval (CI) (44 mg N/kg soil, 504 mg N/kg soil]), the only system to have significantly increased from 2010. Increased storage of total N in surface horizons of RT compared with conventional tillage systems is widely reported (Beare et al., 1994; Havlin et al., 1990), although the accumulation rates in our study were somewhat surprising given the relatively short, 2-year time period. Trends in POM-N were similar; the highest soil POM-N in Fall 2012 was observed in the RT system (409 mg POM-N/kg soil) and the least in tilled systems (Fig. 1; 283 to 310 mg POM-N/kg soil). For the RT system, this represents an average 87% [190 mg POM-N/kg soil, 95% CI (49 mg POM-N/kg soil, 331 mg POM-N/kg soil]) increase over 2 years (219 mg POM-N/kg in Fall 2010). In comparison, Eichler Inwood et al. (2015) reported an average of 460 mg POM-N/kg following 2 years of perennial organic forage management at the same research site, slightly higher than that observed from the RT system (409 mg POM-N/kg). Higher POM-N under no tillage was similarly reported in southeastern U.S. soils, with a 2-fold increase in POM-N at the 0 to 5-cm depth in no till vs. conventionally tilled soils following 13 years of management in Georgia (Beare et al., 1994). However, the authors reported no differences in POM-N at the 5- to 15-cm depth. In a study evaluating labile organic matter in several established farming system trials primarily in the midwestern United States, Marriott and Wander (2006) reported 35% to 40% enrichment in POM-N from organic systems as compared with respective conventional controls vs. just 8% to 10% enrichment in total soil N. This pattern of preferential enrichment of N the POM pool as compared with total N was similarly present in our study when compared with soil N at the beginning of the study. Total soil C at the fall sampling in 2012 did not differ among systems and ranged from 12,500 Mg C/kg soil (23.4 Mg C/ha) in Till (+ACC) to 13,900 Mg C/kg soil (26.0 Mg C/ha) in RT (Fig. 2). The RT system was the only system where a significant increase

| Management system | 2010 | 2011 | 2012 |
|-------------------|------|------|------|
| Till (+ACC)       | 7 (0, 15) | 16 (5, 28) | b 20 (7, 33) |
| Till (–ACC)       | 10 (1, 19) | 50 (30, 70) | a 32 (18, 48) |
| RT                | 7 (0, 15) | 26 (11, 40) | b 17 (5, 38) |

| Management system | Sept. | May | July | Aug. |
|-------------------|-------|-----|------|------|
| Till (+ACC)       |        |     |      |      |
| Till (–ACC)       |        |     |      |      |
| RT                |        |     |      |      |

*Till = organic management with spring tillage; ACC = aboveground cover crop biomass; RT = reduced tillage organic management with no spring tillage.

Table 4. Mean total soil inorganic nitrogen (N; ammonium-N + nitrate-N + nitrite-N) as affected by treatment at each sampling.

Fig. 1. Total nitrogen (N) and particulate organic matter-N (POM-N) in Aug. 2012 as affected by management system. Within N fraction, means (bars) indicated by the same letter or no letters are not significantly different, P > 0.05. Dashed lines represent mean total N and POM-N from all plots at study initiation in Sept. 2010. Means indicated by an asterisk (*) indicate a significant (P < 0.05) difference in values between Aug. 2010 and Aug. 2012 for respective treatment plots. Raw data of replicates for total N and POM-N are represented by ‘•’ and ‘○’ symbols, respectively. Error bars are the 95% confidence intervals of the mean. Management systems: Till (+ACC), spring tillage with aboveground cover crop biomass (ACC) retained; Till (–ACC), spring tillage with ACC removed; RT, reduced tillage system with no spring tillage.

Fig. 2. Total carbon (C) and particulate organic matter-C (POM-C) in Aug. 2012 as affected by management system. Within C fraction, means (bars) indicated by the same letter or no letters are not significantly different, P > 0.05. Dashed lines represent mean total C and POM-C from all plots at study initiation in Sept. 2010. Means indicated by an asterisk (*) indicate a significant (P < 0.05) difference in values between Aug. 2010 and Aug. 2012 for respective treatment plots. Raw data of replicates for total C and POM-C are represented by “•” and “○” symbols, respectively. Error bars are the 95% confidence intervals of the mean. Management systems: Till (+ACC), spring tillage with aboveground cover crop biomass (ACC) retained; Till (–ACC), spring tillage with ACC removed; RT, reduced tillage system with no spring tillage.

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was observed compared with 2010 (Fig. 2; from 10,400 Mg C/kg soil or 19.4 to 26.0 Mg C/ha). This increase of 6.6 Mg C/ha [95% CI (1.7, 11.5 Mg C/ha)] compares to 3.1 Mg C/ha total added over the two seasons in poultry litter, and aboveground cover crop biomass C accumulation rates of 4.2 Mg C/ha in each year (i.e., 8.4 Mg C/ha over the two seasons). Soil POM-C trends in Fall 2012 were similar, but the RT system had significantly greater soil POM-C (6803 mg POM-C/kg soil) than both Till systems and compared with the beginning of the study (4029 mg POM-C/kg soil; Fig. 2). Marriott and Wander (2006) reported that total soil C enrichment in organic systems (as compared with relevant conventional systems) was less than relative enrichment of POM-C. Our results were consistent with these trends, and indicated a 34% increase in total soil C as compared with a 69% increase observed in POM-C for the RT system, which is not surprising given the preferential allocation of newly sequestered C to the POM pool (Coulter et al., 2009; Hernandez-Ramirez et al., 2009).

The C:N ratio of particulate organic matter did not differ among treatments in Fall 2012 (average of 17:1), and did not significantly decrease over the course of the study. Trends in POx-C were similar to that observed with POM-C; the highest POx-C was observed from the RT system (255 mg C/kg soil) at the end of the study, but this was not significantly different from Till systems and no management system differed from POx-C at the beginning of the study (231 mg C/kg soil; Fig. 3). In other work at this site, Eichler Inwood et al. (2015) similarly reported lessened response of POx-C to management practices than POM-C after 2 years, potentially due to the short research time period given that POx-C reflects a more processed fraction of labile C (i.e., denser materials of smaller particle size) as compared with POM-C (Culman et al., 2012).

Vegetable crop performance. For the 2011 season, eggplant yield did not differ among management systems (Fig. 4), with similar total yield (mean = 26.7 Mg·ha⁻¹), marketable yield (mean = 17.2 Mg·ha⁻¹), fancy grade yield (mean = 3.8 Mg·ha⁻¹), and culled fruit weight (mean = 9.5 Mg·ha⁻¹) across management systems. Eggplant leaf tissue N was higher in RT (42 mg N/g) than Till treatments (35 mg N/g), potentially indicating more synchronous N availability and plant demand in the RT systems (data not shown). It appears this did not have a significant impact on yield in our study, although it may be important under different environmental conditions. Early season differences in soil N availability (Table 4) did not significantly impact eggplant yields.

For the 2012 season, total, marketable, and fancy grade watermelon yield did not significantly differ among systems, although culled fruit yield was higher in the Till (+ACC) system (Fig. 5). Although not significant due to high variability represented by wide CIs (Fig. 5), total and marketable watermelon yields in RT were about half of that observed in Till (+ACC). Watermelon in RT may have been more negatively affected by weed pressure than eggplant, both due to competitive ability and the greater weed density in these systems in 2012 as compared with 2011 (Table 3). Disease symptoms, confirmed to be caused by Fusarium sp. were observed, but live plant counts indicated no significant differences among systems in plant mortality (P > 0.05; data not shown). Watermelon leaf tissue N did not differ among management systems at the time of sampling (P > 0.05; data not shown), averaging from 29 to 30 mg N/g in all systems.

Over both seasons, the Till (–ACC) system had yields equivalent to the highest yielding treatments, and did not differ from the Till (+ACC) system. Although similar research in systems with aboveground cover crop biomass removal are lacking (e.g., as mechanically harvested or grazed forage), our results suggest that this type of system may be a practical option to provide additional harvestable biomass for organic growers who integrate crop and livestock production. Our results also suggest that soil C building effects of cover crops in these systems may be primarily dependent on root biomass given lack of differences between Till (–ACC) and Till (+ACC) systems, consistent with other reports on the relative contribution to soil C of shoot vs. root carbon (Rasse et al., 2005; Stockmann et al., 2009).
2013). Previous studies have indicated that organic, cover crop–based RT systems can, in some cases, be as productive as tilled systems (Treadwell et al., 2007, 2008) and onion under organic management in the humid south—some cases, be as productive as tilled systems (Treadwell et al., 2007, 2008) and onion under organic management in the humid south—some cases, be as productive as tilled systems (Treadwell et al., 2007, 2008).

Fig. 5. Mean total, marketable, fancy grade, and culled watermelon fruit yield in 2012 as affected by management system. Within fruit grade, means indicated by the same letter or no letters are not significantly different, P > 0.05. Error bars are the 95% confidence intervals of the mean. Management systems: Till (+ACC), spring tillage with aboveground cover crop biomass (ACC) retained; Till (-ACC), spring tillage with ACC removed; RT, reduced tillage system with no spring tillage.

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