Comparing Soil Health and Fertility Outcomes Among Reduced Tillage Practices in Organic Vegetable Crop Production

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Introduction

Organic farmers are adopting conservation tillage methods to protect soil health and fertility when terminating cover crops and preparing fields for planting. Tarping (occultation) has gained popularity as an efficient way to reduce tillage intensity on small vegetable farms, but limited research has been conducted to understand its influence on soil health and fertility. Our multi-year study evaluated the effects of tarping and other organic reduced tillage methods on important soil health and fertility metrics, as well as crop yield. We compared five different tillage and reduced tillage methods for terminating a spring seeded pea-oat cover crop, including: *i*) mow-till *ii*) roll-crimp *iii*) strip-till *iv*) woven-tarp and *v*) poly-tarp.

Methods

Trials were conducted in 2024 and 2025 on two diversified vegetable farms using organic practices, Michigan State University's Upper Peninsula Research and Extension Center (MSU-UPREC) North Farm in Chatham, MI and Full Plate Farm (FPF) in Skandia, MI. MSU-UPREC study area consists of Ensign sandy-loam soil and FPF consists of the Shoepac sandy-loam soil series.

A fully randomized block design containing four replicates of the following five treatments was used at each farm: *i*) mow-till *ii*) roll-crimp *iii*) strip-till *iv*) woven-tarp and *v*) poly-tarp.(n=8). A pea (100 lbs ac^{-1}) and oat (128 lbs ac^{-1}) cover crop was broadcast seeded and later terminated by our treatments on July 8th, 2024 and on June 25th, 2025. Tarps were in-place for 24 days in 2024 and 21 days in 2025 before transplanting vegetable crops.

Soil samples (0-6” depth) were composited from each plot (n= 5 per plot) immediately pre- and post-termination and analyzed for total inorganic nitrogen (IN), phosphorous (P), potassium (K), soil organic carbon (SOC), total active carbon (Active C) and soil microbial enzyme activity levels (MEA), among other parameters.

Linear models were used to estimate mean change in concentration (Δ) between pre- and post-treatment periods for all response variables, and a linear mixed effects model was used to estimate mean soil temperature among treatments during the termination period. The Tukey method was used to for all mean comparisons (α = 0.05) in R.

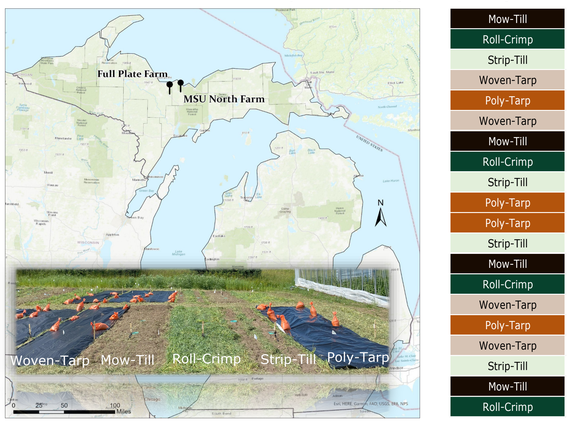

Figure 1. MSU-UPREC North Farm and Full Plate Farm study area locations (MI, USA), treatment types, and fully-randomized block experimental study design.

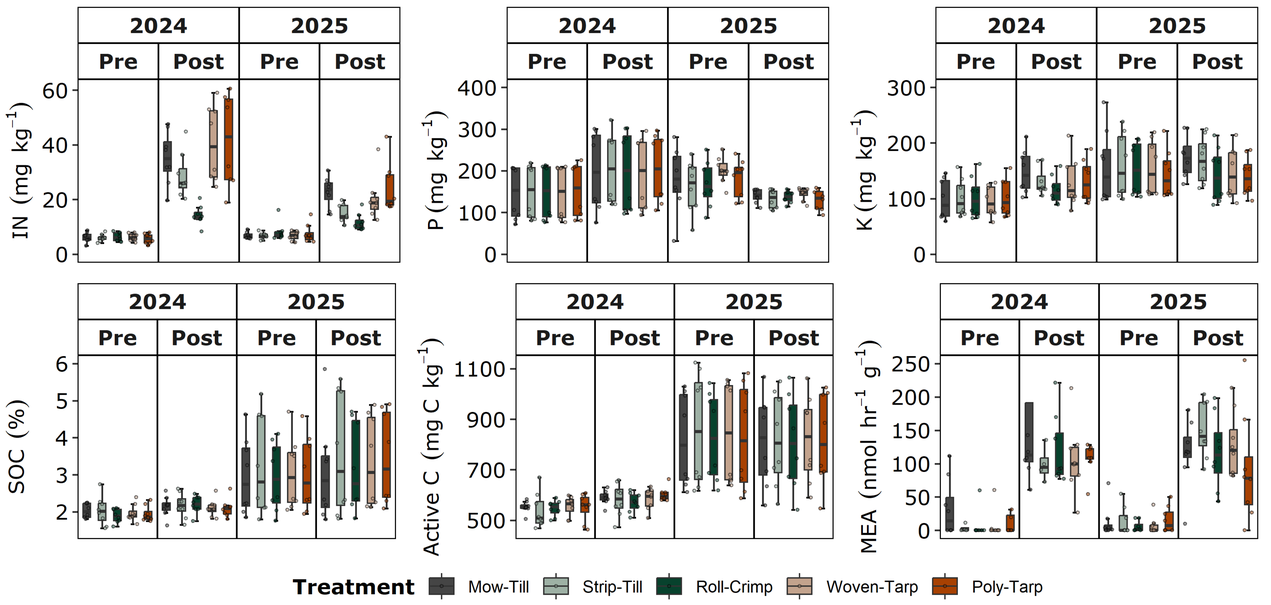

Figure 2. Inorganic nitrogen (IN; top-left), phosphorous (P; top-middle), potassium (K; top-right), soil organic carbon (SOC; bottom-left), active carbon (Active C; bottom-middle), soil microbial enzyme activity (MEA; bottom-right) observations (points) for each treatment during the pre- and post-treatment study periods. Boxplot lines represent median, 25% and 75% quartiles, and whiskers represent ± 1.5× the interquartile range.

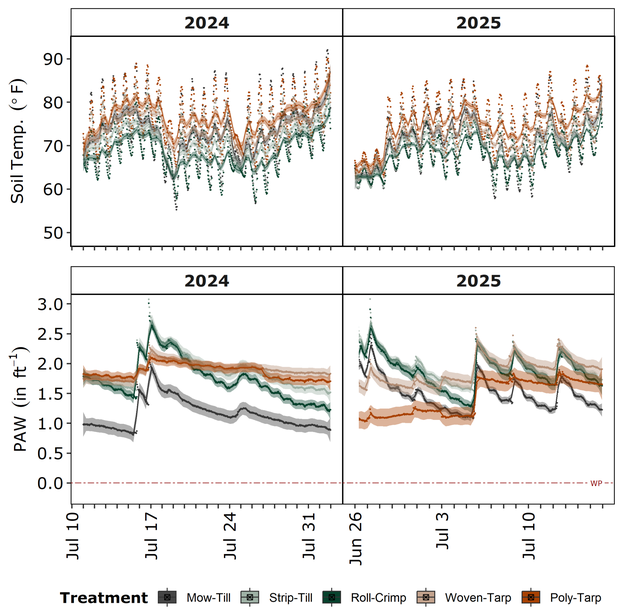

Figure 3. Observed soil temperature (top; °F) and plant available water (PAW; bottom; in ft^{-1}) recorded at 1-hr intervals in each plot (n=8) during 2024 and 2025 where mean (points) and loess smoothing (lines ±SE ribbons) were estimated for each treatment during the cover crop termination period.

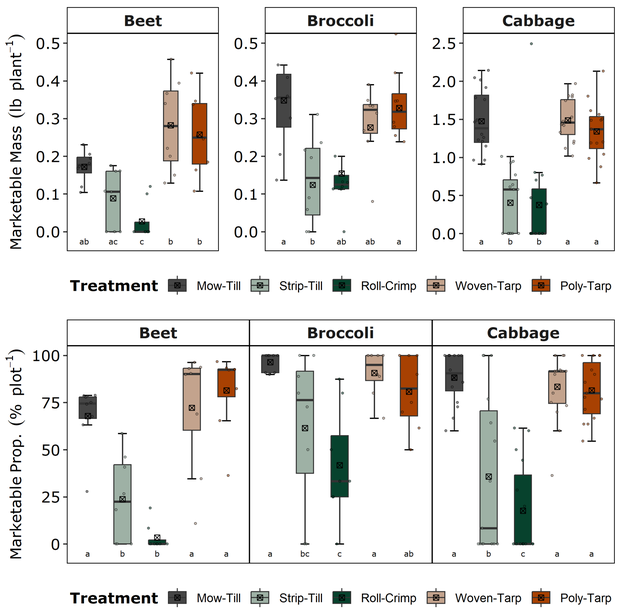

Figure 4. Marketable mass (top; lb plant^{-1}) and marketable proportion (bottom; % plot^{-1}) of beet, broccoli and cabbage observations (points), post-hoc mean estimates (☒), and mean comparisons among treatments ($p<0.05$). Boxplot lines represent median, 25% and 75% quartiles, and whiskers represent ± 1.5× the interquartile range.

Table 1. Summary statistics including degrees of freedom (df), estimated marginal mean soil temperature (Soil Temp.; °F) and Tukey post-hoc mean tests (MT; $p<0.05$). Linear models were used to estimate mean change (Δ; ± standard error) between pre- and post-treatment study periods, for inorganic nitrogen (IN; mg kg^{-1}), phosphorous (P; mg kg^{-1}), potassium (K; mg kg^{-1}), soil organic carbon (SOC; %), active carbon (active C; mg C kg^{-1}) and soil microbial enzyme activity levels (MEA; nmol hr^{-1} g^{-1}) where number of observations (n) was the same for all soil health and fertility Tukey post-hoc mean tests ($p<0.05$).

Treatment	df	Soil Temp. (°F)	MT	n	ΔIN mg kg^{-1}	MT	ΔP mg kg^{-1}	MT	ΔK mg kg^{-1}	MT	ΔSOC %	MT	ΔAct. C mg C kg^{-1}	MT	ΔMEA nmol hr^{-1} g^{-1}	MT
Mow-Till	9.1	72.1 (±0.5)	a	16	21.0 (±3.7)	a	5.8 (±10.7)	a	34.1 (±5.9)	a	0.07 (±0.02)	a	16.2 (±14.8)	a	107.0 (±98.7)	a
Strip-Till	9.1	70.5 (±0.5)	b	16	13.7 (±2.4)	b	13.6 (±10.7)	a	19.2 (±5.9)	ab	0.17 (±0.04)	a	1.8 (±14.8)	a	112.7 (±127.4)	a
Roll-Crimp	9.3	68.8 (±0.5)	c	16	5.1 (±0.9)	c	10.1 (±10.7)	a	0.8 (±5.9)	b	0.19 (±0.04)	a	2.3 (±14.8)	a	104.8 (±96.7)	a
Woven-Tarp	9.5	73.0 (±0.5)	d	16	20.8 (±3.7)	ab	-5.2 (±10.7)	a	13.0 (±5.9)	ab	0.14 (±0.03)	a	2.1 (±14.8)	a	103.5 (±95.5)	a
Poly-Tarp	9.3	75.8 (±0.5)	e	16	22.7 (±4.0)	a	0.5 (±10.7)	a	12.7 (±5.9)	ab	0.18 (±0.04)	a	20.8 (±14.8)	a	66.7 (±61.6)	a

Results

Mean ΔIN of mow-till (21.0), woven-tarp (20.8) and poly-tarp (22.7) were statistically similar and significantly greater than ΔIN of the roll-crimp (5.9), while ΔIN of strip-till (13.7; mg kg^{-1}) was intermediate and similar to only the woven-tarp treatment (Table 1; Figure 2).

Mean ΔK in mow-till (34.1) was significantly greater than roll-crimp (0.8; mg kg-1), but similar to the other treatments (Table 1). No significant treatment differences were detected for ΔP.

Poly-tarp (20.8) and mow-till (16.2) mean ΔActive C were considerably larger (more than 7x) when compared to strip-till (1.8), roll-crimp (2.3), and woven-tarp (2.1). However, ΔActive C values were not significantly different among the treatments (Table 1). Mean MEA levels increased following all treatments, however no significant ΔMEA treatment differences were detected (Table 1; Figure 2).

Marketable proportion of all crops harvested in mow-till, woven-tarp and poly-tarp was significantly greater than strip-till and roll-crimp, except for broccoli where poly-tarp and strip-till performed similarly. Marketable mass of crop plants was statistically similar across the mow-till, woven-tarp and poly-tarp treatments, which generally yielded more than the strip-till and roll-crimp treatments (Figure 4).

Discussion

When compared to roll-crimp, all other treatments showed significantly greater IN increases pre- to post-treatment, indicating that cover crop and soil organic nitrogen were rapidly converted to inorganic nitrogen during the treatment period. Mow-till, woven-tarp and poly-tarp treatments were most effective for increasing IN, likely due to higher soil temperatures under tillage and tarps (Table 1; Figure 4).

K levels increased the most following mow-till, and moderately increased following strip-till, woven-tarp, and poly-tarp treatments (Table 1) indicating these treatments effectively incorporated cover crop residue to release K and make it bioavailable.

Numeric increases in Active C under mow-till and poly-tarp suggest that these treatments effectively incorporated C from cover crop residues to enhance its availability and short-term soil health.

Woven-tarp and poly-tarp treatments produced crop yields and quality similar to mow-till, indicating these may be viable reduced tillage methods for growers. Other factors such as farm logistics, labor and profitability must also be considered to provide recommendations and make practical decisions on cover crop termination methods.

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